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The Man Who Delivers the Goods

and something about "habits" that applies to you and to me and everybody else

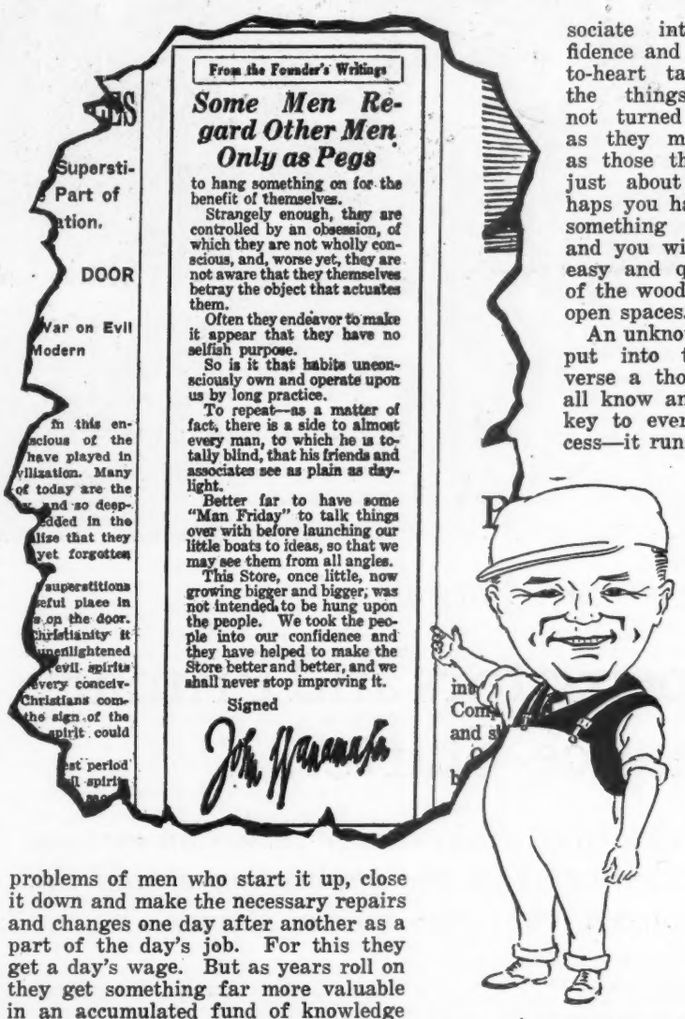
HERE is a snack of wisdom from a plain man who established his name and an institution that is known in its line the world around. As we pause to note the incoming of a new year on our calendars and in the dates we write, we can well afford to roll over in our minds the remarks in this clipping from a recent advertisement in the *New York Times*.

"Habits," said John Wanamaker, "unconsciously own and operate upon us by long practice." A larger hunk of truth could hardly be expressed in ten other plain and understandable words. Year by year we are growing older and should be growing wiser and more thoughtful about the future and the present and be able to judge as to how well we are taking advantage of our opportunities and using our accumulated knowledge and experience. But that thing habit to which is attached indifference, procrastination, and laziness, both mentally and physically, is the log in the way on that path along which we feel we should march proudly to success with our share of glory attached to accomplishment. It is easy to pass the buck to the other fellow, and to circumstances, and miscellaneous other hindrances, but when we stop and think to ourselves, its really that thing "habit" that's holding us back.

Sure! I've got habits and bad ones at that, but I know it and have to fight 'em all the time—that's the reason this comment by John Wanamaker has struck home in me so deeply and caused me to pass it on to prick you a little. Personally, I have passed the stage where I get a thrill out of the happenings and experiences of a younger day and I like to sit and dream about the future and the things that are to be in the world that I know most about. This is the world of machinery and the problems of men who start it up, close it down and make the necessary repairs and changes one day after another as a part of the day's job. For this they get a day's wage. But as years roll on they get something far more valuable in an accumulated fund of knowledge and experiences that cannot be purchased, lost or stolen. As we march on in point of time, this fund of knowledge becomes a bank account on which we can earn a small or an adequate return according to whether we follow the habits of the spendthrift or the habits of the investor. And there you have that thing "habits" coming up.

In this clipping he said another good thing: "Better far to have some Man Friday to talk things over with before launching our little boats to ideas." Now, at the beginning of this new year 1926, is a good time to do some new thinking and new planning along this line. Perhaps you have had some good ideas but time has shown that your judgment cannot always be trusted. If you know this is true admit it and take your boss or some other successful associate into your confidence and have a heart-to-heart talk. Go over the things that have not turned out as well as they might, as well as those that have been just about right. Perhaps you have overlooked something he will see and you will discover an easy and quick way out of the woods and into the open spaces.

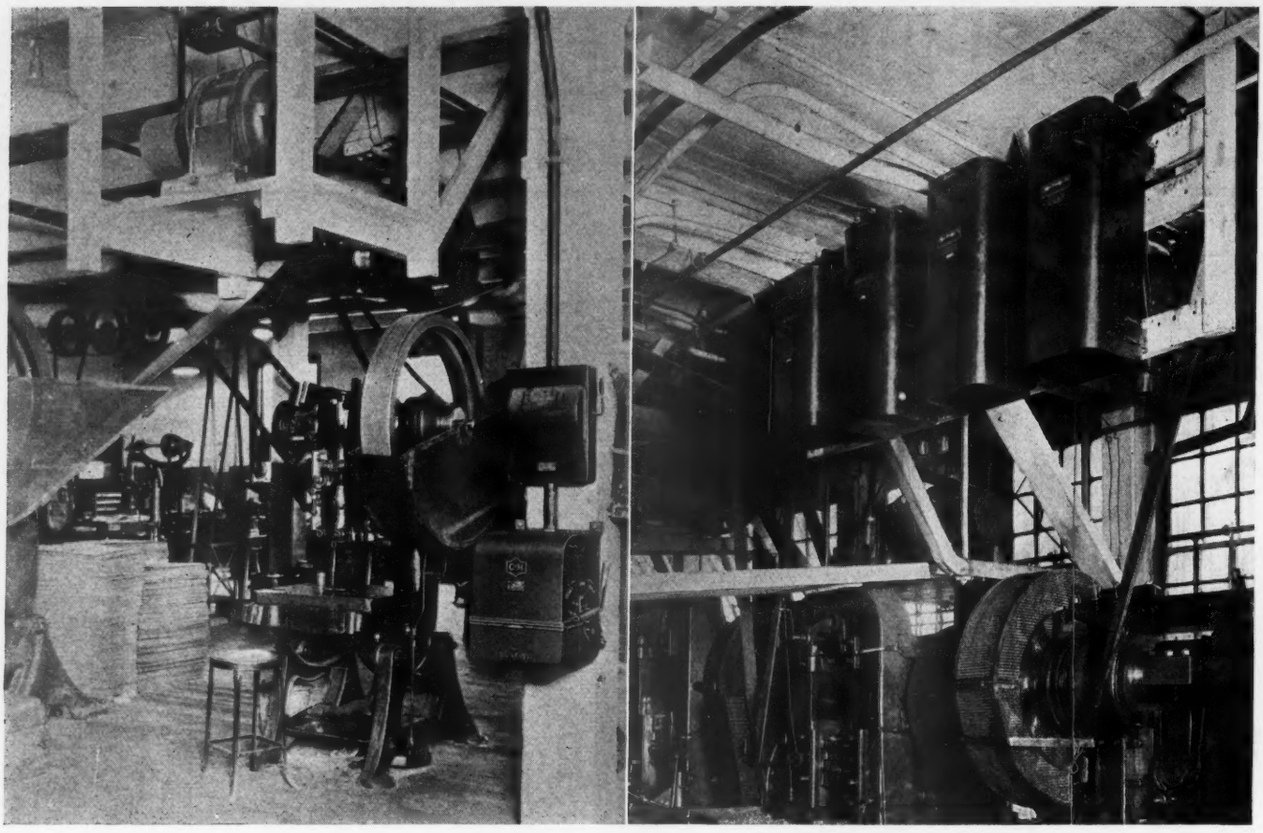
An unknown author has put into the following verse a thought that we all know and that is the key to every man's success—it runs like this:


From the Founder's Writings
Some Men Regard Other Men Only as Pegs
to hang something on for the benefit of themselves.
Strangely enough, they are controlled by an obsession, of which they are not wholly conscious, and, worse yet, they are not aware that they themselves betray the object that actuates them.
Often they endeavor to make it appear that they have no selfish purpose.
So is it that habits unconsciously own and operate upon us by long practice.
To repeat—as a matter of fact, there is a side to almost every man, to which he is totally blind, that his friends and associates see as plain as daylight.
Better far to have some "Man Friday" to talk things over with before launching our little boats to ideas, so that we may see them from all angles.
This Store, once little, now growing bigger and bigger, was not intended to be hung upon the people. We took the people into our confidence and they have helped to make the Store better and better, and we shall never stop improving it.
Signed
John Wanamaker

There's a man in this world who is never turned down,
Wherever he chances to stay;
He gets the glad hand wherever he goes,
Or wherever the farmer's make hay.
He's greeted with pleasure on deserts of sand,
And deep in the isles of the woods;
Wherever he goes there's a welcoming hand,
He's the man who delivers the goods.

The year 1926 is going to discover many such men among those who read this, but remember what John Wanamaker said about Habits and that Man Friday.

Practical Pete



Here are applications of compensators and primary-resistance starters to similar service. At the left is a Cutler-Hammer manually-operated compensator controlling the motor driving a punch press. On the right is a group of Allen-Bradley automatic, primary-resistance starters which are used to start the motors driving punch presses. Inasmuch as the latter starters are push button controlled they can be located wherever conditions permit—in this case they are mounted on the ceiling.

Operating characteristics of

Compensators and Primary Resistance Starters

as used for starting squirrel-cage induction motors, including comments on the application of and the results obtained from each type of starter

Symposium Conducted by
ARTHUR J. WHITCOMB
Associate Editor, Industrial Engineer

WHEN starting a squirrel-cage induction motor by applying line voltage directly to its terminals, a starting current of six to eight times full-load current may be drawn from the line. This starting current may not be objectionable on large power systems, particularly in the case of motors of 7½-hp. capacity and smaller, but inasmuch as excessive starting current results in objectionable line disturbances, practically all public utilities have definite regulations regarding the size of squirrel-cage motor that can be put directly across the line.

The starting current of a squirrel-cage motor depends upon the voltage impressed on the primary or stator terminals of the motor and is independent of the torque against which the motor is to start. The peak current at starting is of short duration, for the current falls quickly to the normal running value as the motor accelerates. The duration of the starting period depends upon the character of the load to be started. Inasmuch as the initial rush of current is controlled by the voltage impressed on the motor, this voltage may well be reduced to a value that is little more than sufficient to start the load under all normal conditions.

Reduced potential for starting is commonly obtained either by the use of auto-transformers or by using resistance. The older and probably more common practice involves the use of auto-transformers in compensators or auto-starters. A compensator consists usually of two and sometimes three auto-transformers arranged with different voltage taps so as to supply the desired voltage.

With the primary-resistance method of starting, reduction of the voltage impressed on the motor is secured by the insertion of resistance in series with the primary or stator windings of the motor. The amount of resistance may be adjusted to secure the desired starting voltage and torque. As the motor attains speed, the resistance is cut out in one or more steps.

Primary-resistance starting differs distinctly from the compensator method in that the latter causes a reduced voltage of constant value to be impressed on the motor, whereas

with the primary-resistor method, the voltage impressed on the motor varies according to the current taken by the motor. The initial inrush of current causes a large drop in voltage over the resistors; hence the initial voltage impressed on the motor is low and gradually increases as the motor speeds up and the motor current decreases.

Compensators reached a higher point of development earlier than the primary-resistor starters and hence the use of compensators is more general. However, rapid progress has been made in recent years in the development of primary - resistance starters. At the present time there is uncertainty in the minds of many users of electrical equipment regarding the application and use of each type of starter. Many operators favor compensators, while others are just as decided in their convictions that the primary-resistance method gives better results. To help clear up this question and to aid our readers in deciding which type of equipment is better suited to the conditions to be met in their own plants, the Editors of INDUSTRIAL ENGINEER asked the leading manufacturers of compensators and primary-resistance starters to discuss the characteristics and application of these two types of equipment.

Points that should be considered in the selection and application of these two types of starters are: line disturbance, line current, power factor, power taken from line, torque, duration of starting period, losses and efficiency, smoothness of operation, ease of control, reliability, ease of repair and maintenance, size and application, and cost. These points are fully covered in the discussions which follow.

* * * *

T. E. Barnum, Chief Engineer, The Cutler-Hammer Manufacturing Company, Milwaukee, Wis.—In the selection of a motor for a given application, motor characteristics are usually considered first. In the following discussion, it is assumed that the standard squirrel-cage motor has been selected as meeting the general requirements and that the only question is, whether a primary resistor or an auto-transformer will be used to reduce the voltage at the motor terminals at starting. To answer this question, several factors must be considered, which will be discussed in the following:

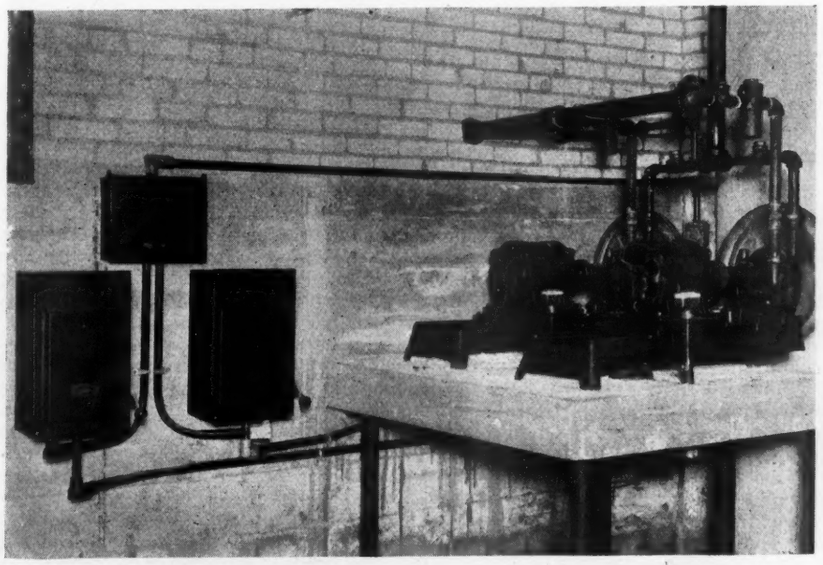
Line Disturbance.—The severity of line disturbance depends on the conditions of the particular installation, such as load on the circuit, capacity of the transformer bank, size of the conductors, and similar factors. Any statement is, of course, purely comparative. For example, assume that the motor can be started with 65 per cent of line voltage applied to the motor terminals. If, because of the general conditions, the drop in voltage on the line is 4.4 per cent when an auto-transformer is used, then the drop would be 5.5 per cent if a primary resistor were used. Similarly, where with the auto-transformer the voltage drop might be 1.7 per cent, with primary resistors the corresponding drop would be 2.2 per cent. This small difference is due to the better power factor of the resistor method.

Line Current.—The current taken from the line at the moment of starting is materially less with the auto-transformer than with the primary resistor, but not quite in proportion to the ratio of transformation, due to the magnetizing current of the transformer. In order to give some comparative figures, certain tests were made on a 20-hp., 440-volt, three-phase, 60-cycle, 1,720-r.p.m., squirrel-cage motor. When adjusted to give about 65 per cent of line voltage at the motor terminals with the rotor blocked, the line current with the auto-transformer was 260 per cent of the rated motor current, while with a block of resistance in each of the three phases of the primary circuit, the line current was 340 per cent of the rated motor current. When adjusted to give about 80 per cent of the line voltage at the motor terminals, the line currents were 390 per cent with the auto-transformer and 450 per cent with the primary resistor. These figures may also be taken as representing the performance of the average motor of 10 to 30 hp.

Power Factor.—The power factor of the line at the moment of starting is materially higher with the primary resistor than with the auto-transformer. When adjusted to give 65 per cent of line voltage at the motor terminals for starting, the power factor with the primary resistor runs from 80 to 85 per cent, depending upon the motor size; whereas with an auto-transformer, under the same conditions, the power factor of the line runs from 50 to 60 per cent, varying again with the size and characteristics of the motor, motor speed, and the like.

Power From the Line.—Power taken from the line at the moment of starting, measured in kilowatts, is materially less with the auto-transformer than with the primary resistor, partly because of the reduced line current but largely because of the reduced power factor. When line disturbance is not taken into account and with 65 per cent voltage applied to the motor, the power taken from the line at the moment of starting with an auto-transformer is about 50 per cent of that which would be taken with a primary resistor. Similarly, with 80 per cent voltage applied to the motor, the power taken from the line with an auto-transformer is about 60 per cent of that taken with a primary resistor. However, if the time to accelerate to full speed is considered, the difference in energy taken during this period is not so large, because the time is shorter when a resistor is used than with an auto-transformer.

Torque.—The torque developed by the motor in question is independent of the method used to reduce the voltage at its terminals and, for a given motor, depends only on the actual voltage impressed on it. For modern applications of such a motor, a fairly high torque is required of the motor due to the fact that the load to be started is fairly heavy. Starting conditions for such a squirrel-cage motor are very rarely what may be called light, and quite generally such a motor is called upon to develop very nearly its full load torque at the moment of starting. For a motor of 1,800 r.p.m. synchronous speed, about 80 per cent voltage is necessary at the motor terminals, to



Manually-operated primary-resistance starters are used on this installation.
They control the motors driving the fans and pumps of an oil burning equipment installation. Cutler-Hammer starters are used here.

develop this torque. As stated above, the line current with the auto-transformer is somewhat less than that with the primary-resistor method. Conversely, of course, for a given line current, the torque that may be developed at the motor is materially higher when an auto-transformer is used, because a higher voltage can be applied at the motor terminals.

Smoothness of Operation.—Considering the acceleration of the motor, after it has once started to rotate, there are many advantages with the primary resistor method. As the motor accelerates, the line current decreases, which automatically increases the voltage at the motor terminals. Thus the torque at the motor builds up much faster when the primary-resistor method is used, and the motor comes up to speed in a shorter time. Again, there is no loss of torque while the motor is being accelerated to full speed, since the resistor may be cut out of circuit in one or more steps without opening the circuit, whereas with the usual auto-transformer starter, the circuit is opened in passing from the starting to the running position, giving a momentary high current peak and, unless the change is made quickly, will result in some decrease in speed of the squirrel-cage motor.

Size and Application.—In general, when considering the application of a standard squirrel-cage motor, the only question involved is the permissible starting current that may be taken from the line. The National Electric Light Association has developed certain rules for permissible starting currents, which limit the use of this type of motor on central station supply lines to 30 hp. and below. It is probable that up to and including 20 hp., the primary-resistor method can be used under almost any condition. For 20 hp. and larger, judgment must be used, depending upon the particular motor application, power supply, etc. It is, of course, possible to build primary-resistor starters of any size for use in starting low-voltage, squirrel-cage, induction motors.

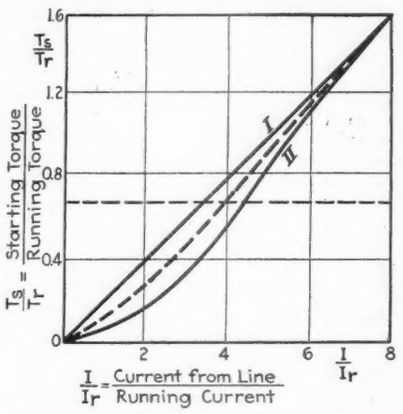
Cost.—For moderate sizes of motors, the size and cost of the primary-resistor starter are less than for the corresponding auto-transformer starter. This difference will vary somewhat with the voltage reduction supplied, since considerably more resistance material is required to reduce the motor voltage to 65 per cent than is necessary to reduce it to 80 per cent.

Ease of Control.—As regards ease of control, care is necessary with both types. Perhaps a little more skill is necessary with the auto-transformer type because of the requirement that the transition from the starting to the running step must be made very quickly.

Then, assuming that other conditions are equal, there is no advantage either way on the score of safety or reliability. Maintenance is, of course, a matter of the design of the starter in question. Assuming that both methods use the air-break type of contact, there should be no difference in maintenance.

G. O. Wilms, Chief Engineer, Allen-Bradley Company, Milwaukee, Wis.—There are two types of primary-resistance starters. In one type the resistance is cut out in one step; sometimes, however, two or more steps of resistance are used. In the other type, the resistance is gradually cut out steplessly by compressing the resistor. This latter type is known as the compression resistance starter and is the type made by my company.

Both of these types of starters provide two distinct advantages over the compensator—one is that the voltage on the motor will gradually increase as the starting current decreases with the increasing speed of the motor, and the other is that the motor is not disconnected from the line when connected



Line currents required by compensators and primary-resistance starters for various values of starting torque.

Curve *I* is the current drawn from the line by the compensator while Curve *II* represents the current taken by a primary-resistance starter. The vertical scale is expressed as the ratio of the starting torque required to the running torque. The horizontal scale is given in the ratio of the current taken from the line to the running current. It will be noticed from these curves that for a given starting torque, a larger starting current is required by the primary-resistance method, as shown in curve *II*. However, the higher the starting torque required, the closer will the two curves coincide, thereby diminishing this advantage.

to full voltage, thereby reducing the second current inrush to a minimum. However, let us consider in detail the characteristics of both compensators and resistance starters.

Line Disturbance.—The question as to the line disturbance caused by a primary resistor starter will best be answered by the oscillograph curve shown on page 6. This oscillogram shows the starting characteristic of a 20/25-hp. motor started in 1½ sec., with manually-operated, compression resistance starter. Even under these conditions there are no sudden peaks.

Line Current.—The resistance-type starter will take proportionally more current from the line depending on the voltage required to start the motor.

Power Factor.—Since the transformers used in the average compensator are not very efficient, the exciting current is rather high, thereby giving additional reduction in power factor.

Losses.—The losses during starting will be higher with the resistance-type starter since actual power is dissipated in the resistors. These losses will get proportionally smaller as higher voltages are required to start the motor. Losses during starting will only become of importance when motors are started frequently, but will be more than offset by the reduced line disturbances and shock to the driven machine.

Efficiency.—The primary-resistance starter will take more current from the line than the compensator, and the difference is greater the lower the tap used on the compensator. If, however, the compensator is connected to the 75 per cent or a higher voltage tap this difference is not very much. This condition has been shown in the diagram on this page. An investigation of large compensator installations made some years ago would indicate that the majority are connected to the 75 per cent or higher taps in order to be able to start the motor under all load conditions. If, for instance, a motor will start at 70 per cent voltage on an average, but the load is such that a higher voltage is required at times, the compensator would have to be connected to a higher tap. With the primary-resistance starter of the graphite-compression type, it would only mean additional pressure applied to the compression resistors, which can be applied by the operator, to get the motor started on the heavier loads. In such cases the power taken from the line as an average may be even higher with the compensator than with the resistance-type starter.

Cost.—Up to 100 hp. the cost of the compression-resistance starter is in line with average compensator prices. For higher horsepower the graphite-compression type starter becomes more expensive.

Torque Available from Motor.—Since the current is under the control of the operator, the torque will also be. Inasmuch as the voltage automatically increases across the motor terminals as the starting current reduces, a higher torque is obtained even if no additional resistance is cut out after the motor has once started. This is the reason that a single-step, primary-resistance starter will give good starting conditions.

Smoothness or Freedom from Shock in Equipment Driven.—Due to the small current inrush and the possibility of building up the starting current to just the value at which the motor starts, the driven machine can be started very gradually without any shock. This will prevent belt-slipping and reduce the strain on gear-driven machinery.

Space Requirements of Each Type.—Up to 100 hp. the Allen-Bradley starter is built in the wall type, and for above 100 hp. it is made in the floor type. The larger starters have a tendency to get bulkier than the compensators, which is primarily due to the air-break switches used which require more room. But when it comes to motor sizes above 50 hp., the size of the

starting equipment is not of such vital importance. For smaller starters which are frequently grouped, the average space taken by compensators can very well be met.

Ease of Control.—Since the hand levers in the case of manually-operated starters are thrown in one direction only, mistakes in starting are practically eliminated. Operating handles can be furnished with a delay in action so that the operator cannot accelerate the motor too rapidly.

Reliability.—The statement can very well be made that primary-resistance starters are just as reliable as the compensator. Since the primary-resistance starters all use air-break switches, which are easier to inspect than the oil-immersed type switches used with the average compensator, their reliability is rather higher than lower.

Ease of Repair and Maintenance.—Since no oil switches are used, inspection is easy. The starters are mounted as a unit inside of a cabinet from which they can easily be taken out for repairs. Resistance units can be withdrawn by removing two connections.

Sizes in Which Each Type Is Made.—Graphite-compression type starters for squirrel-cage motors, both hand and automatic types, are made up to 400 hp. for all voltages. The newest type of hand starters manufactured by the Allen-Bradley Company are all of the semi-automatic type and are made in sizes up to 100 hp. The starting switch is inside the resistance unit for this size. For larger sizes, the starting contacts are magnetically-operated switches. Since the first current inrush is only 30 to 50 per cent of normal full-load current, very little flashing is experienced on the starting contacts.

Safety to Power Service and Workmen.—All starters are fully enclosed, providing safety to workmen. Starter covers can be locked closed. Stopping on all hand starters is accomplished by a stop button on the outside of the cabinet. Due to the small current inrush very little line disturbances are experienced, thereby reducing main line fuse blowing to a minimum.

Character of Applications to Which Each Type of Starter Is Particularly Adapted. — Primary-resistance type starters can be used everywhere that compensators are used. Where machinery has to be started carefully or where line disturbances have to be kept to a minimum they are superior to compensators.

Are There Any Applications to Which You Do Not Recommend One or the Other of These Two Types of Starters?—The only place where an investigation is necessary before a primary-resistance type starter can be used is where large, squirrel-cage motors have to be started from a limited power supply. In such cases, the compensator, if the motor can be started on a low tap, is better adapted, since less power is required to start the motor. There are, however, cases where the primary-resistance type starter works out better, and these are where the power plant has sufficient momentary overload capacity if the governo. is given time to act, which can be accomplished by building up the load gradually with a primary-resistance type starter.

We are naturally very enthusiastic about the graphite-compression type starter and are thoroughly convinced that this method of starting is superior. Power companies in large centers of distribution like New York, Chicago, Detroit, St. Louis, are beginning to realize that the amount of power used during starting is not so objectionable as long as this power is drawn slowly enough.

* * * *

W. C. Yates, Manager, Industrial Controller Sales, General Electric Company, Schenectady, N. Y.—The size of squirrel-cage induction motors that may be started without any current limiting means is determined by two considerations: First, the regulations of the power supply company and, second, the strength of the motor windings in view of the strain imposed.

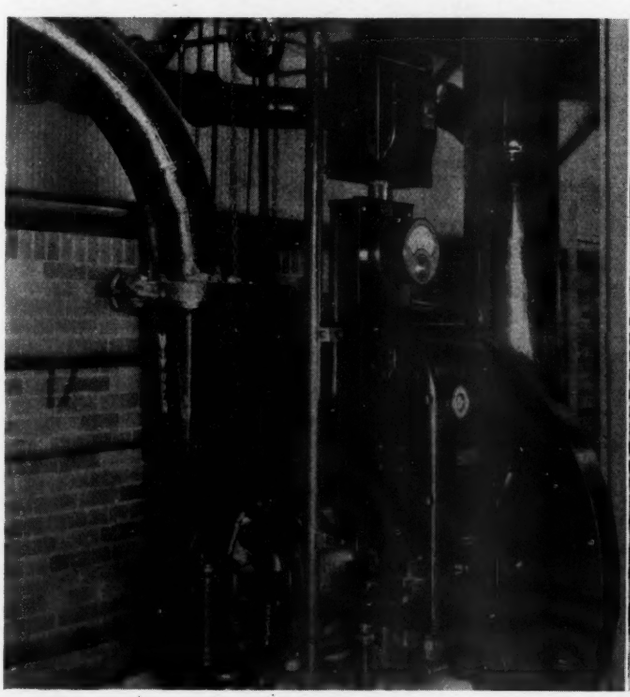
Most power companies put out printed regulations which make more or less definite statements as to the size of squirrel-cage motors that may be thrown on the line without a starter. Frequently, however, when special cases are taken up with them, rulings are made which permit throwing larger squirrel-cage motors across the line than are indicated by the printed regulations.

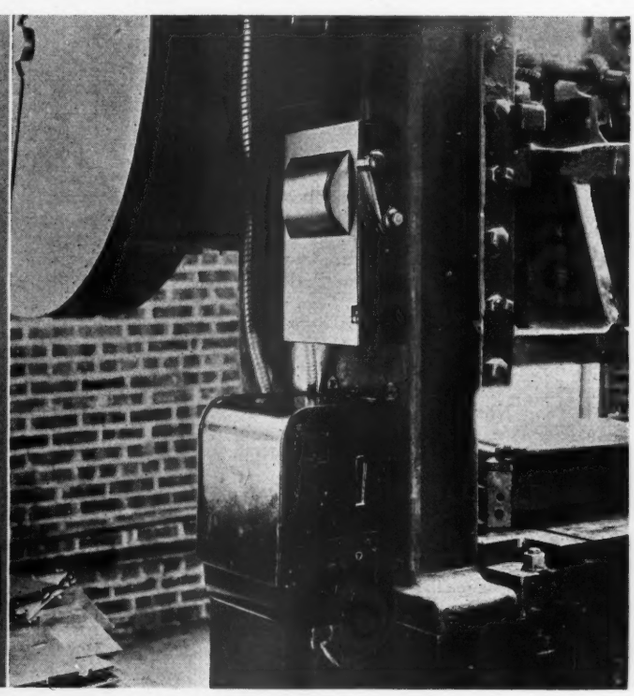
Squirrel-cage motors may well be thrown directly on the line to start whenever it is permissible. Such is now the generally accepted practice for starting motors up to 7½ hp. and, as far as the better grades of motors now on the market are concerned, could safely be done with motors up to 20 hp.

When the starting current must be limited, there are two common methods of accomplishing this: by a compensator (or auto-transformer) or by a resistor in the primary circuit. The

Two applications of manually-operated compensators to squirrel-cage motors.

At the left is a General Electric compensator controlling a motor rated at 20/25 hp., 3,600 r.p.m., 220 volts. Notice the very convenient arrangement of compensator, ammeter, and safety switch, all on the same pipe frame mounting. At the right is a manually-operated compensator controlling the motor driving a shear. The starting duty on an application of this kind is severe, inasmuch as a heavy flywheel must be accelerated. A Westinghouse auto-starter, or compensator, and safety switch are used in this installation. Notice the use of flexible conduit for machine wiring.





compensator has long been the standard for general application, if numbers mean anything, but of late years the advocates of the primary-resistor starter have made themselves heard sufficiently to raise several questions which many industrial plant operators would like to have answered.

The resistor starter in general practice may be considered as a half-way step between the auto-transformer or compensator starter and the full voltage or across-the-line type starter. Generally, the resistor starter provides approximately 80 per cent of line voltage, and the compensator starter about 60 per cent of line voltage. We then have these three lines:

(1) Full voltage starters, generally applicable to 7½-hp. motors and less.

(2) Resistor starters giving 80 per cent line voltage, applicable to motors from 10 to 20 hp.

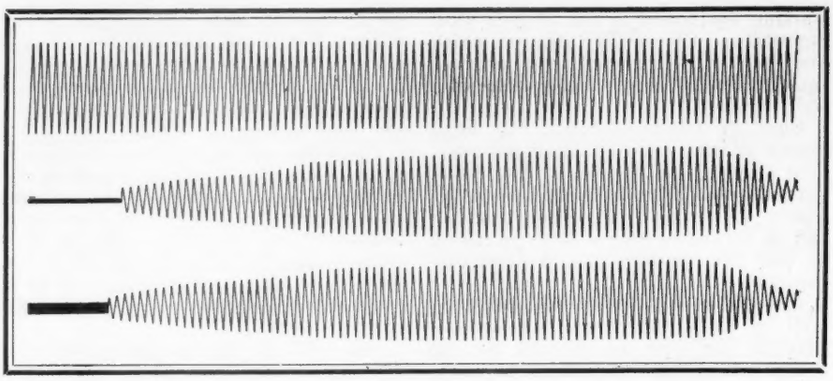
(3) Transformer starters giving usually 60 per cent of line voltage, but readily adjustable to give higher or lower voltages, and applicable to larger motors.

For small sizes of motors (up to about 20 hp.) on low voltage, the primary-resistor starter has some advantages over the compensator in regard to size, weight, and cost. It provides a better accelerating characteristic, in that as the motor accelerates and as the line current decreases, the voltage on the motor and consequently its torque increase. This is at the expense of a larger initial current inrush drawn from the line than a compensator requires, which means that the starting current limitations of central stations and the starting torque required of the motor must be considered before applying a resistor starter. With the same *line* starting current a compensator will give 60 to 80 per cent greater starting torque.

With the resistor starter, the line circuit is not broken and made again, as is the case upon the throw-over from starting to running on a compensator. The circuit is maintained, and the second accelerating peak, which occurs when the resistance is shorted out, is therefore less than the second peak on starting with a compensator. However, this does not matter greatly, for with a compensator the second current peak which may, under certain conditions, be higher than the initial inrush, lasts for but a few cycles and has no noticeable effect upon the line voltage. An oscillogram shows practically no voltage drop.

This second current peak does have an effect upon the motor itself but it is not objectionable until we reach sizes of several hundred horse power when use of the Korndorfer method with its transition feature becomes advisable. This method, however, does not eliminate the starting compensator.

Those who advocate the stepless resistor starter claim that it offsets many of the arguments made against the resistor starter. It is true that a gradual increase to that current that will start a motor is of advantage in minimizing the effect on the line voltage, but apart from that, this type is open to the criticisms that can be laid against any resistor starter. Then, too, the gradual increase is more of a theory than an actuality in service with a manual starter; and it cannot be taken advantage of in a magnetic starter.



Oscillograph record of the line voltage and motor current during starting with primary resistors. This oscillogram was taken on a 25-hp., three-phase, 220-volt, squirrel-cage, induction motor while being started with an Allen-Bradley primary-resistance starter. The top curve shows the actual alternations of the line voltage during the starting period. The drop in line voltage during this starting period is 4.8 per cent. The two bottom curves represent the current flowing in two of the legs of the motor. As may be seen, the current starts at a small value and gradually builds up to the point where the motor starts accelerating. The current then gradually decreases. The ratio of the starting current to full-load running current in this case is 2.8 to 1. The duration of the starting period was 1.5 sec.

A compensator is a voltage changing device, and a resistor is an energy dissipating device. For motors above 20 hp. where long and frequently repeated starts must be made, a resistor to have the same capacity as a compensator would be larger and more expensive.

The primary-resistor starter has a place in the application field for the smaller motors and may be used with larger motors driving centrifugal pumps, fans or other light starting loads. A properly-designed compensator has no limitations as the right starter for general applications and can, therefore, be so recommended. In larger sizes, low voltage, and in all high-voltage starters, the resistor method is at a disadvantage as to size, weight and cost for equal capacity.

* * * *

J. S. Rowan, President, The Rowan Controller Company, Baltimore, Md.—In comparing primary-resistance starters with compensators they can be compared from two general standpoints. The first to consider, and which is probably the oldest comparison, is the question of line disturbance.

When considering line disturbance it is first absolutely necessary to eliminate the hand starter of either type because with the hand starter the line disturbance is going to depend upon how the operator starts the motor.

A number of power companies have made a lot of current rulings and at the same time are selling their customers hand-operated equipment which surely seems, to the writer, to be ridiculous. The only way line disturbance can be controlled is by means of an automatic starter where the time of acceleration is automatically taken care of and thereby taken out of the hands of the operator.

In comparing the question of line disturbance, tests made by the writer have shown that on light starting jobs the automatic compensator gives less line disturbance than the primary-resistance type and this is the only point at which the compensator shows up more favorably than the primary-resistance type. However, this does not apply in certain classes of machines such as fans, blowers and other centrifugal devices.

On the very heavy starting jobs, where high starting voltages are required, the line disturbance is more favorable to the primary-resistance starter because the initial peak is approximately the same, whereas the second peak of current is far less in the case of the primary-resistance starter than with the compensator.

In regard to power factor it is self-evident that the primary-resistance starter is very superior and in plants where there is a heavy penalty for power factor, primary resistance is often justified from this standpoint alone.

To my mind, however, the question of line disturbance is only part of the story and in many cases is a very small part. The big factor in a great many cases is, How do the two types affect the cost of production? When compared from this standpoint I feel that there is very little room for comparison.

The question of throwing the operating lever from the starting to the running position, of the two types, is inherently simpler with the resistance type and, other things being equal, simplicity is bound to mean greater reliability.

Of course, fair-minded people will recognize that either type is subject to failure and burnouts sooner or later, especially on hard service jobs. There is this difference, however, between the two types. The primary-resistance type can be repaired much easier and at far less cost, consequently eliminating a considerable delay in the shutting down of the machine which

very often runs into big money and greatly affects production costs of plants. In fact, any plant that employs their own electricial men rarely has any need for a costly delay with the primary-resistance type, as the resistance contactor can temporarily be blocked in until the time can be spared for the proper repairs. I believe that this little feature is the big deciding one as to the relative advantages of the two types.

Primary-resistance starters are manufactured by The Rowan Controller Company in standard sizes up to 300 hp. and will be built on special order in larger capacities.

* * * *

H. D. James, Manager, Control Engineering Dept., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.—There is a general tendency towards the use of full-voltage starting for squirrel-cage, induction motors. This does not require either a resistor or auto-transformer starter. The rules of the various power companies limit the inrush current in starting motors where the customer is connected to a low-voltage distribution network or where several customers are supplied from transformers of limited size.

However, large industrial establishments are not limited by these rules. Some of these large users have been experimenting with full-voltage starters for motors as large as 100 hp., where the design of the motor was checked to see that the windings would stand the strain of the initial current inrush.

Recently, some motor manufacturers have been experimenting with squirrel-cage rotors having two windings. One is a high-resistance winding which is close to the surface of the rotor and has a high resistance so as to give good starting characteristics. The second winding is embedded in the iron and absorbs very little power at slow speeds on account of the inductive effect of the iron surrounding the conductor. As the motor approaches full speed this winding takes the load on account of its low resistance and serves as the operating winding, practically short-circuiting the high-resistance winding on the surface of the rotor. By changing the proportions of these windings the speed-torque curve of the motor can be given a variety of shapes. Experience with this type of motor is, however, too limited to make any predictions regarding its general use. It has the advantage that the motor itself has the necessary features for limiting the inrush current at the time of starting and, therefore, a much simpler form of controller can be used.

Much has been said regarding the effects of open circuit transition from the starting to the running point in many auto-transformer starters. For most motors under 200 hp. such a discussion is largely academic.

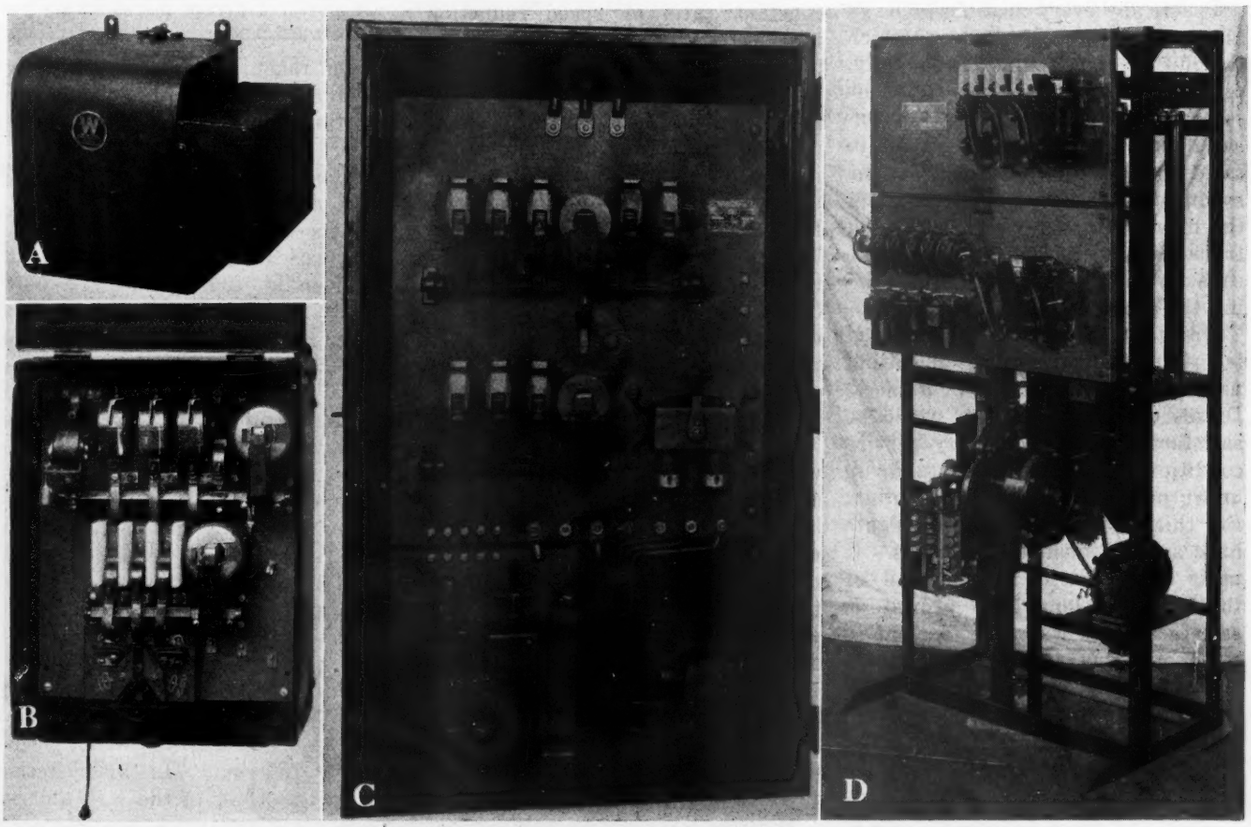
The writer believes that the real reason for selecting one type of reduced voltage starter rather than another, is simply a matter of cost and convenience. The resistor starter is a power consuming device. For small motors which may be started at 80 per cent of normal voltage the energy lost in starting is small and the resistor type of starter is not bulky. Larger motors require starters which will reduce the voltage to 65 per cent of normal, which makes a much larger resistor type of starter. For some applications 65 per cent of full voltage will not start the motor, so that it is necessary to obtain permission to use 80 per cent of full voltage for starting. Standard starters should, therefore, provide both voltages, particularly for motors of 25 hp. or larger. This means a rather large resistance starter.

The transformer type of starter has relatively small losses and can be made compact and of a convenient shape. It is, therefore, the most desirable type for many applications.

In general, either type of starter may be used within certain limitations. The convenience to users, however, will probably be the controlling factor rather than the power consumed during starting or the question of open-circuit transition from starting to running.

Push button operated automatic starters for squirrel-cage motors.

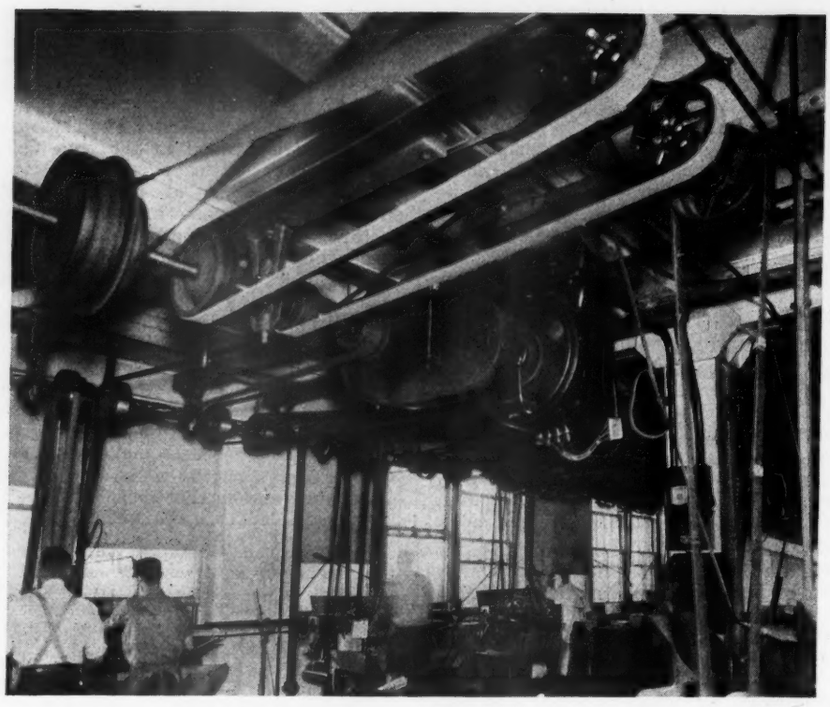
At *A* is shown a Westinghouse automatic auto-starter or compensator. The smaller case at the right contains a magnet which furnishes the motive power for operating the oil switch in the bottom of the larger case. In *B* is shown the General Electric automatic compensator. The switching, as can be seen, is done by air-break contactors. This starter has a thermal overload relay, shown at the bottom of the illustration. *C* shows a Westinghouse automatic compensator using air-break switches. The auto-transformer can be seen at the lower left. At *D* is shown an Allen-Bradley, gradual start, automatic, primary resistance starter. The timing and sequence of operations on this starter are controlled by a pilot motor driving a drum controller and a cam for varying the resistance, in conjunction with time and current accelerating relays.



Some examples of

Silent Chain Drives on Industrial Equipment

including an analysis of the reasons for using such drives, and the operating results obtained from them



One of five silent chain drives in the screw-machine department of The Addressograph Company, Chicago, Ill.

Several years ago The Addressograph Company installed a Link-Belt silent chain on one of their lineshaft drives in the screw machine department and have since adopted chains for all similar drives in this department. One of the reasons for doing this was the desire to get a definite and unvarying speed of the lineshaft, as the operation of the screw machines is based on the speed of the lineshafts, which are operated at 208 to 220 r.p.m.

By FRANK E. GOODING

Associate Editor, Industrial Engineer

INDUSTRIAL plant operating men find that most power transmission drives operate with very little trouble. This is often due to a light load or to ample provision in the power transmission equipment to take care of any load.

Practically every medium or large plant, however, has drives which continually give trouble. Frequently, on drives which do not operate under severe service conditions, this unsatisfactory service has been due to an attempt to save by estimating the rating too closely when designing the drive. In such cases, providing transmission equipment of ample capacity is the only means of solving the problem.

On many types of drives the load is of a fluctuating, or pulsating nature or is in the form of a shock. Drives of a rating which would be satisfactory under ordinary service conditions often do not stand up under more severe variable loading. For this type of service many plants have applied silent chain drives. It must be admitted that not all of these installations have proved as satisfactory as was expected, but in most cases an investigation would show that the trouble was not due to the chain itself but to the way that it was applied. One of the most common causes of trouble is neglect to take into account the fact that extraordinary service conditions require an extra capacity in the chain.

Air compressors and refrigeration machinery represent a heavy type of service. When motors were installed on compressors in service to replace the steam engine drive many plants installed silent chain drives on them. This permits putting the motor up close to the compressor and gives a constant ratio of speed reduction irrespective of whether the compressor is operating under an overload or with a light load. This latter advantage has become one of the important advantages of chain drives in that a definite number of revolutions of the driven machine result from each revolution of the driver. This is also one of the principal reasons for the adoption of silent chain drives on many other types of equipment. An installation with a motor drive on a two-stage air compressor connected by a Link-Belt silent chain is shown on page 10.

Still another operating condition which puts a very heavy load on a chain drive is in connection with a lineshaft drive to the tumbling barrels in a foundry. As the barrels revolve, the contents roll and shift, thus causing intermittent jerks, which are transmitted back to the drive. In such cases, care must be exercised to see that the drive is of sufficient capacity to take care of the shock of the shifting load. Such over-loads are strains on the metal in the chain, and this condition can only be taken care of by providing capacity in the chain sufficient to withstand the load without undue stress.

A good example of a tumbling barrel drive is shown on page 12. Here the lineshaft is connected to a battery of 12 tumbling barrels and is driven at 100 r.p.m. by a 565-r.p.m., 25-hp. motor, through a Morse chain in the plant of the Towner Mfg. Co., Cleveland, Ohio.

Blowers and ventilating fans are still another type of severe service which taxes the drive connected to them. Ordinarily chain drives for this and practically all other types of equipment are mounted with a comparatively short center distance which is determined approximately by the pitch and the diameter of the sprockets. In the installation pictured at the top of page 9 an induced draft fan operating at 300 r.p.m. is driven through a Ramsey silent chain by a 30-hp. motor operating at 750 r.p.m. In this case the fan was so close to the wall and so

large in diameter that the motor had to be installed entirely beyond the fan. This made it necessary to operate the drive on 84-in. centers.

Chains are coming into wide use on conveyor drives as they can be connected up to give a considerable reduction in speed on the first step. One of the illustrations on page 10 shows an American High Speed chain driving a pan elevator conveyor over 100 ft. long for handling sand. This is driven by a 200-hp., 720-r.p.m. motor with a step down to 235 r.p.m. for the driven shaft. The remainder of the reduction is through gearing. This 200-hp. drive consists of two strands of 1¼-in. pitch chain; each strand is 12 in. wide.

A type of drive somewhat similar to a conveyor drive, in that there is a considerable reduction in the speed of the driven equipment, is used on the traveling ovens in biscuit and cracker bakeries as is shown on page 12. In this case a 7½-hp. motor is connected to a Reeves variable-speed drive by a Ramsey silent chain to give a speed reduction in the first step of 1,150 to 355 r.p.m. The chain is operated on 30-in. centers.

In the larger proportion of cases chain drives are designed for stepping down the motor speed instead of stepping it up. However, in the Chicago plant of a candy manufacturer, a sugar pulverizer, operating at 3,600 r.p.m., is driven from a motor operating at 800 r.p.m. This gives a step-up in the speed ratio of 4½ to 1. The motor shaft is extended at both ends and a sprocket

Ordinarily silent chain drives are operated on short centers, but this drive is on 84-in. centers

Because this induced draft blower was placed so close to the wall that the motor could not be installed alongside it, the long center was necessary. This blower is driven by a 30-hp. Ramsey silent chain.

is also placed on each end of the shaft, which connects through the chain to the pinion at the end of the pulverizer shaft. A 35-hp., 800-r.p.m., 220-volt, d.c. motor is used on this drive, which is shown on page 11. The shaft and rotating parts in the pulverizer weigh somewhat over 300 lb. and must be very carefully balanced. A Morse chain is used.

SKF thrust bearings are placed at each end of the shaft and operate under continuous lubrication from a sight-feed oil cup. Plain ball bearings are used for the radial support of the pulverizer shaft in the bearings located between the pinions and the rotating part. The guard on the chain was removed when this photograph was taken.

To operate this shaft at 3,600 r.p.m., it is necessary for the chain to travel at a very high speed, and in order to insure satisfactory operation it was necessary that the chains be placed in special relation to each other. The keyways in the sprockets and pinions were cut very carefully and centered on the center line of a tooth. The sprockets on each end of the shaft were also lined up and cut as accurately in line as possible. This was necessary because if one chain were pulling just a little ahead of the other there would be a noticeable whip in the chain, which, at the high speed, would give very unsatisfactory operation. The installation as originally made operated very satisfactorily. However, after it had been in operation for some months, the shaft in the pulverizer was accidentally bent. In installing the new shaft the keyways were cut a fraction of an inch out of alignment. This caused one chain to pull a little ahead of the other and, due to the high speed of operation, resulted in a very serious whip in the chain. When a new offset key was made and installed, which takes care of misalignment of the keyway, the pulverizer operated as well as before.

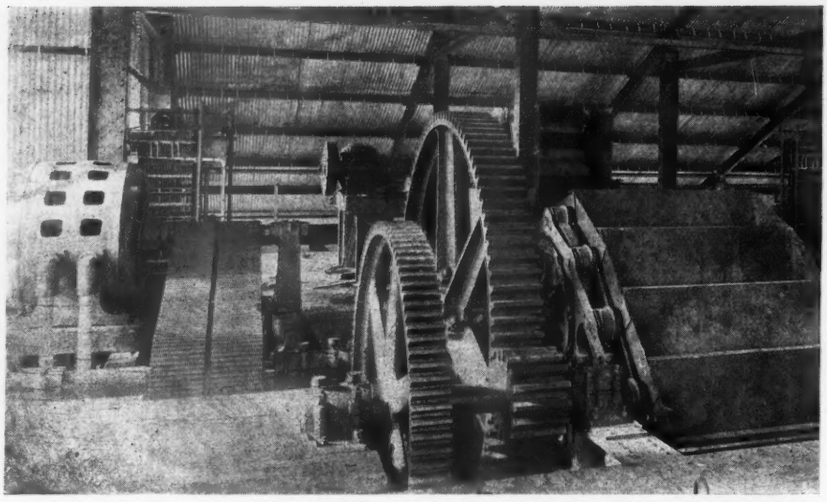
This chain is lubricated by applying oil to the back of the chain with a brush, about once a month. The small pulley placed on the end of the motor shaft, as may be seen in the illustration, drives a countershaft overhead which is connected to the elevator, that supplies sugar to the pulverizer, and to the blower which blows the pulverized sugar into the bags of the centrifugal separator.

Before the chain was installed, this pulverizer was driven from the same motor by two special, rawhide belts on 18-ft. centers. The installation of the chain, of course, reduced considerably the floor space required. Previously there had been a great deal of difficulty in keeping the tension of the two belts identical, so as to obtain a positive, even drive on each end of the pulverizer.

When the tension on one belt exceeded that of the other, the result was the same whip as when the

Four silent chain drives are used in this installation.

The two lineshafts in the foreground are operated at 500 r.p.m. from a motor connected through a short-center American High Speed silent chain. This is an installation of brass polishing and buffing wheels at the plant of the Chicago Faucet Company. The other two lineshafts operate at a lower speed.



This 200-hp. chain drive is connected to a pan elevator conveyor.

This drive is used to handle sand on an elevator over 100 ft. long. The 200-hp. American High Speed silent chain is made up of two strands of 1¼-in. pitch chain each 12 in. wide and connects a 720-r.p.m. Allis-Chalmers motor to a shaft operating at 235 r.p.m.

two chain sprockets were slightly out of alignment. The life of these two rather expensive belts was short, which made the drive a very expensive one. The chain has been in operation now over a year and a half and has not caused any trouble except during the few days after the new shaft was installed, as has already been explained.

In making this installation, an additional allowance was made above the 17½ hp. for each chain which would normally be considered sufficient for operating the drive, as the motor is rated at 35 hp.

Another interesting experience with a silent chain drive occurred in a lead mill. Previous to 1908, the method of driving the high-pressure hydraulic pumps used in the operation of lead pipe presses at the Chicago plant of the Raymond Lead Works, had been a source of considerable trouble. It was practically impossible to prevent some water leaking from around the pistons and getting onto the belts.

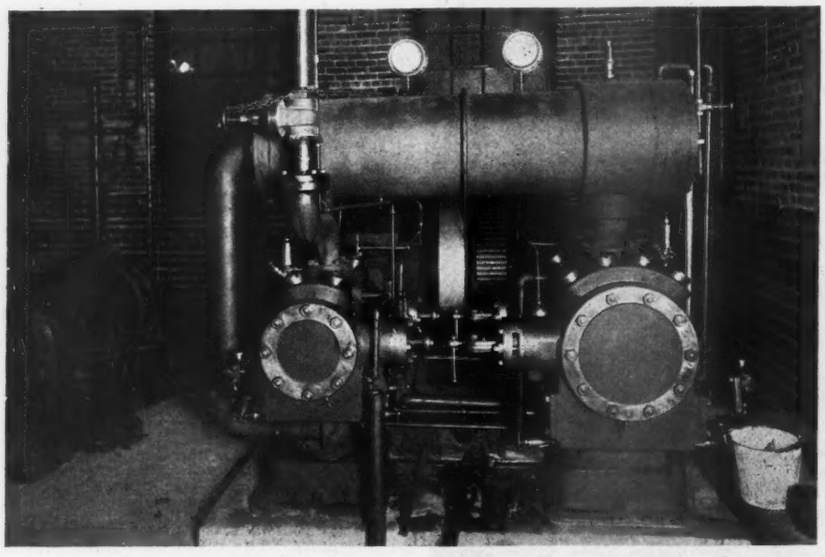
In 1908 at the recommendation of Earl C. Moss, consulting engineer, Chicago, Ill., Morse chains were installed on each press pump lineshaft, which in turn were driven by two 50-hp. motors through belts. These chain drives have operated at practically no cost and with very little attention until 1924 and 1925 when some of the sprockets, some links, and one or two of the chains had to be renewed.

In addition to this, two sheet lead rolls are also driven by silent chain. In these mills both rolls reverse; that is, the motor reverses at the end of each pass and the sheet is returned through the rolls. One of these mills is operated by a 75-hp. motor and the other by a 50-hp. motor. Both of these drives have stood up well under the strain of the rapid reversals.

In heavy-duty work such as on pumps and on rolling mill drives much depends upon using a chain of ample size for the heavy duty involved. The overloads are momentary and the motors are always designed with an ample factor of safety for such service. The point which too many users of silent chains overlook is that the chain also must be of a capacity fully capable of standing the overload which might be placed upon it. It must be remembered that electrical apparatus shows the effect of overloading largely by heating and unless the overload is continuous or far above the capacity of the equipment, no serious results follow. On the other hand, the mechanical elements of a drive have a specific stress or load rating above which it is not advisable to go. For this reason while a motor is capable of handling a temporary overload of 50 per cent, it is never advisable to use a chain which is so small that it may be subjected to a 50 per cent overload. In such cases, a chain of 50 per cent greater capacity will give much more satisfactory service and is always advisable. This is also true of all other mechanical elements in a drive, such as gears, clutches, couplings, or other auxiliary parts of the drive.

In the Chicago plant of Philip Ruxton, Inc., manufacturers of printing inks, Link-Belt silent chain drives have supplanted gears in connecting the motors to the ink rolls. The motors are mounted on the floor alongside the machines. An ink roll consists of three rolls geared together, and operated separately at ratios of approximately 1:3:9, in ordinary practice.

These rolls are so close to each other that some provision must be made to stop the machine quickly if any foreign matter should get into the rolls. This is done through the shearing pin in the drive gear. If even a wiping rag should get in



Compressor drives such as this, operate under severe service conditions.

This is a two-stage, cross-connected air compressor drive which is connected to the motor through a Link-Belt silent chain. Due to the severe service under which a compressor drive operates, an additional horsepower rating according to a service factor is required when designing the drive.

between the rolls the extra load would shear the pin and so stop the machine. The gear would continue to revolve on the shaft, but the connection between the gears and the shaft would be broken.

These drives have been in use for several years with only an occasional renewal of a link. The drives are not totally inclosed and so do not operate in a bath of oil; however, they are lubricated frequently by brushing the backs of the chain with a brush dipped in oil. The manufacture of ink does not create dust which can get into the chain. Each machine has its own speed reduction, which is not uniform on all machines; most of them, however, operate at a reduction of approximately 1 to 4 or 1 to 6. The load on this service is very constant, particularly as some of the mills operate almost continuously.

Another ink manufacturer uses a variety of drives according to the special problems involved in the work. In the main factory where inks of standard colors are produced in large quantities and the mixing rolls are operated almost continuously, the machines are driven from lineshafts. Under such conditions lineshaft drive with belts to the rolls is considered more economical.

In the branch factories, however, the larger proportion of the work consists of small runs to prepare ink of special colors to match samples. These runs are comparatively short with considerable idle time in between for cleaning up the machine before the next run. For this reason it has been considered more advisable to use an individual drive on each machine. Originally, belt drives on above 10-ft. centers were used in one of the plants. These, however, occupied considerable floor space. As it was desired to economize on floor space and add additional mills, each mill was changed over to a short-center, American High Speed chain drive.

Another interesting application of chain drive is in connection with some special machines for polishing reflectors for floodlights at the Chicago plant of The Pyle-National Co. These machines consist of a number of spindles or heads driven by a single motor. With the older type of machine, these spindles were each driven through a gear. However, the abrasive material used in the polishing process soon wore out the gears, so that they quickly became noisy.

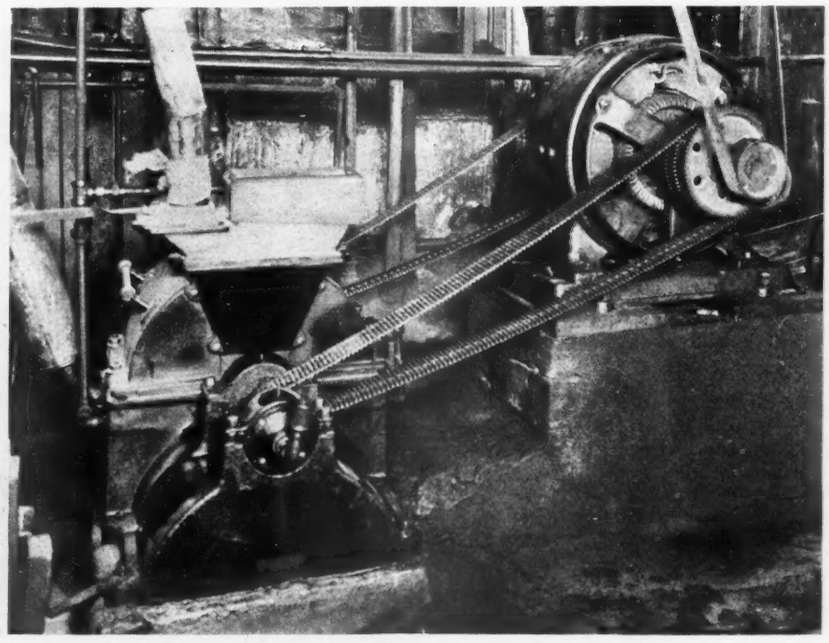
The machines have all been redesigned, so that instead of gearing each spindle is driven by a Link-Belt silent chain. The chain drive is not only quiet, but it has been found that the wear is much less and the life of the chain and its sprockets is considerably longer than was the case with the gears. The chains are subjected to moisture and abrasive material, and operate under practically the same conditions as did the gears.

Several years ago The Addressograph Co., Chicago, Ill., installed a Link-Belt silent chain on the lineshaft driving a battery of screw machines. The advantages found to result were a decrease in the maintenance cost and attention required by the drive. Formerly the belt had to be tightened frequently and occasionally the group of machines had to be shut down to repair the drive. This left the men idle in the meantime. When belts to the individual machines require attention only the one machine is interfered with; any interruption on the main drives stops all. Since then four other batteries of screw machines have similarly been equipped with Link-Belt chains on the lineshaft drives.

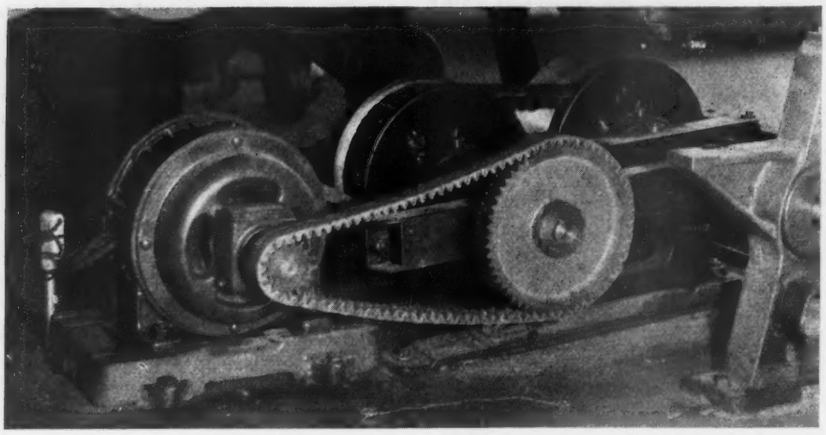
Another advantage of chain drives, which has been of value in the experience in this plant, is that a chain gives a positive reduction in speed. Here fixed lineshaft speeds, which range from 208 to 220 r.p.m. are used on the different drives. These speeds are used in determining what output should be expected of any machine and in setting the speed and feed gears of the screw machines. The chain dips in a bath of oil in the lower half of the case.

On lineshaft drives it is often necessary or advisable to make the lower part of the chain case hinged and fasten the upper half to the ceiling because generally the upper part of the case cannot be lifted high enough to permit inspection.

Buffing or polishing wheels are generally operated from lineshafts or are individually motor-driven. As the wheels operate at high speed, the lineshaft is usually driven at a speed much higher than in the case of the ordinary lineshaft installation. In the plant of the Chicago Faucet Co., short lineshafts are connected to groups of eight buffing or polishing machines. The lineshafts are driven by 15-hp., 1,200-r.p.m. induction motors and operate at 500 r.p.m. SKF ball-bearing hanger boxes are used throughout. The motors are mounted on the ceiling and are connected to the lineshaft by American High Speed chains. The principal reason for using chain drive was the difficulty of operating belts and pulleys in the heavy atmosphere of abrasive dust which would



On this drive a silent chain is used to step up the speed.
In a Chicago candy factory a sugar pulverizer is operated at 3,600 r.p.m. by a 35-hp. motor. The pulverizer is driven through Morse silent chains at each end of the head by a motor with an extended shaft. It was necessary in this case to line up the keyways in the shaft and in the sprockets so that the teeth would be in perfect alignment and fit into both chains simultaneously.



A type of drive installed as standard by a large manufacturer of biscuits and cookies.

Here a 7½-hp. Ramsey silent chain is connected up to a Reeves variable-speed drive to give an immediate reduction of 1,150 r.p.m. to 355 r.p.m. This drive operates on 30-in. centers. The variable-speed drive permits a large variation in the speed of travel of the oven, to take care of quick- or slow-baking products.

settle on the belt and act like emery on the pulleys. These chain drives are totally enclosed and dip in lubricant in the lower part of the case.

In another factory groups of light punch and forming presses are operated from lineshafts. Two shafts are driven by 20-hp. motors and two other shafts are driven by 15-hp. motors connected to the shaft by American High Speed chains. The shaft operates at about 275 r.p.m.

Silent chains were used on this installation because it was desired to have the shafts operate at a very definite speed, which would be known to be exact when determining the speed of operation of each individual machine. Before the chain drives were installed the lineshafts operated at speeds lower than was thought to be the case, and so production figures based on the estimated speed of the lineshaft were in error by several percent. In some cases this had been caused by using pulleys which were available and would give what was considered to be "approximately" the right speed.

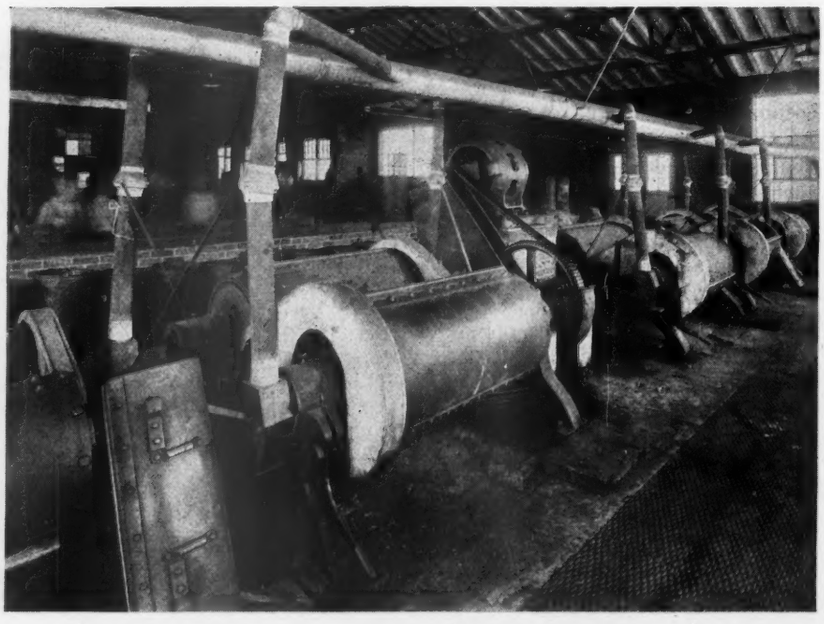
A manufacturer of envelopes has installed a number of ½- to 2-hp. American High Speed chain drives on various machines in his plant. Most of these chain drives replaced gear drives which became very noisy as soon as the gears were slightly worn. As most of the help in plants such as this is composed of girls and women, quiet operation of equipment is a very important factor in keeping the better class of workers.

The first of these chains was installed about four years ago and additional chains have been put on various machines since then, as they have been taken down for overhauling. Some of the motors operate at 1,750 and others at 1,200 r.p.m. Reductions of 3 to 1 and higher are made on the various drives. On one of the first machines on which a chain drive was installed, the motor previously had been mounted about 5 ft. away to one side of the machine so as to give room for the belt drive. This arrangement prevented the operator from passing around the machine except on the one side and also occupied considerable floor space. A new sprocket was placed on the shaft and the motor brought up and mounted directly under the machine and connected to it by a short chain drive. The end of the shaft which extended out from the side of the machine to carry the belt pulley was cut off and the operator can now pass around the machine on either side, which permits him to operate two machines. Expansion of the department made it necessary to shorten up all of the drives to gain additional floor space so that now all machines are chain driven.

A number of other machines were connected to the motors directly through gears. A set of gears would last from a year to a year and a half, when, due to the abrasive action of the paper dust which would get into them, they had to be renewed. A set of gears and pinions for a drive cost $14, while the sprocket and chain for a similar drive cost $16; that is, the cost of the gears was about $10 a year, compared to a cost of $16 for the chain spread over several years.

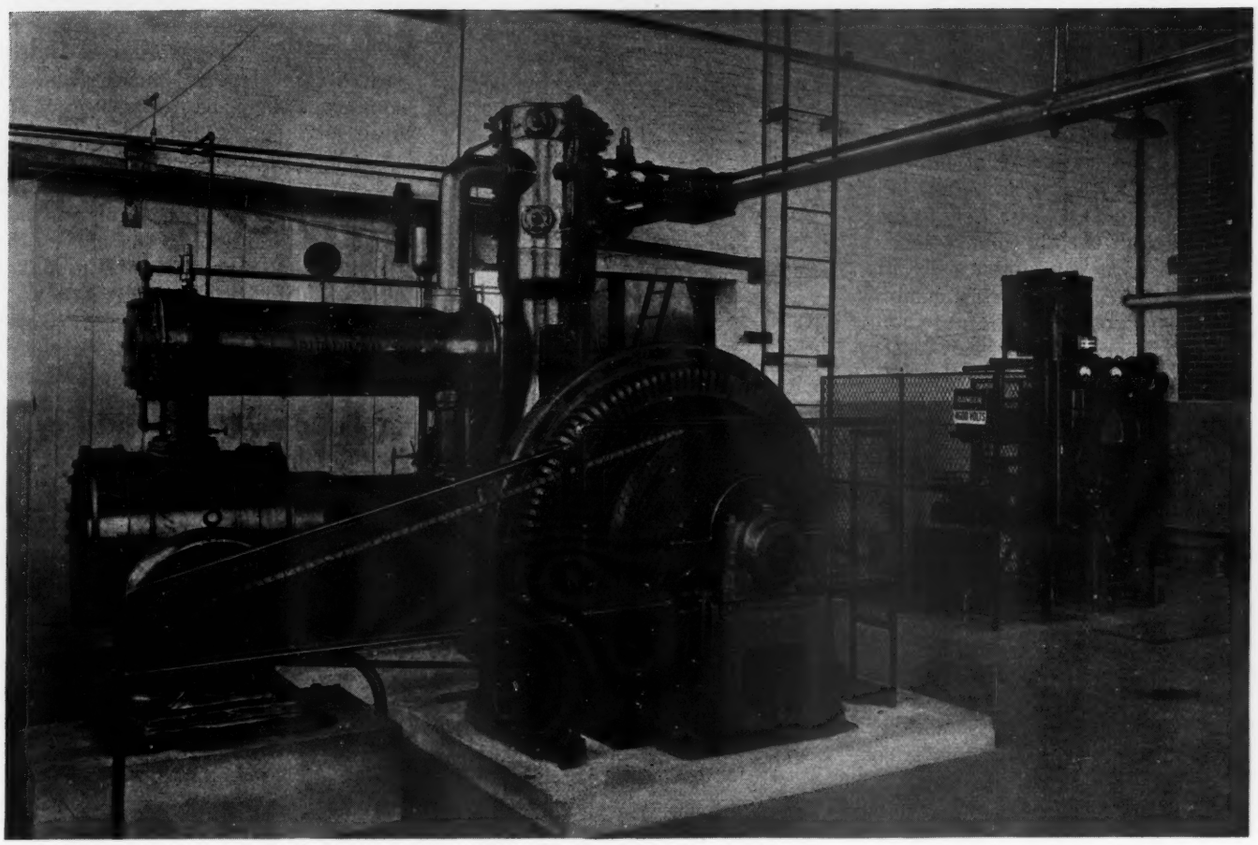
These chains are set back under the machine sufficiently to be protected and prevent paper from getting down into them. When the machines are idle on Saturday afternoons, a man wipes paper lint off all drives and oils the chains from the back with a brush.

Shearing pins are a part of each driven sprocket. This is especially necessary in envelope cutting machines where there is always the possibility of something getting into the way of the die and stopping the machine during the stroke.



Due to the shock load a tumbling barrel drive presents unusual operating conditions.

This battery of 12 tumbling barrels at the Cleveland, Ohio, plant of the Towner Mfg. Co., is driven through a lineshaft by a Morse silent chain connected to a 25-hp. motor operating at 565 r.p.m. This is a 1.2-in. pitch chain, 4 in. wide, operating on 54-in. centers.



The synchronous motor is pre-eminently adapted for the great majority of air compressor drives. In this illustration a synchronous motor is direct connected to a Sullivan Machinery Co. angle compound (two stage) compressor. Manually-operated control (shown at right) is used for starting. This installation is in the plant of the Enterprise Foundry Co., at Detroit.

Factors to consider when selecting

Power Drive Equipment for Air Compressors

including type and capacity of motor required, kind of control apparatus necessary, and the type of mechanical connection that should be used for coupling the motor to the compressor

By GORDON FOX
Electrical Engineer, Freyn Engineering Company, Chicago, Ill.

MANY and varied are the uses of compressed air. Industrial uses of this form of power are confined mainly to furnishing the motive force for portable tools such as drills, reamers, hammers, and riveters, as used for steel fabrication, miscellaneous factory maintenance, and quarrying; for air hoists and air chucks as used in machine shops; for sandblasting and for general cleaning of electrical and mechanical equipment; for paint sprays or mechanical painting devices; and for the agitation and propulsion of liquids and semi-liquids found in some industrial and chemical processes.

Inasmuch as compressed air can be readily carried through pipes to the point of consumption it is the more common practice to compress the air at one or more central locations which are connected to a pipe distribution system. Compressors are located near points of large air consumption and the pipe lines carry the air to any other places where use of it may be required.

Selection of the motor, control, and mechanical power drive equipment for an air compressor depends upon many factors, among which are type of compressor, character of load, method of unloading, pressure required, speed of compressor and the like. An understanding of the types of air compressors will aid in the proper application of power drive equipment to them.

For compressing moderate volumes of air at fairly high pressures, compressors of the reciprocating, displacement type are particularly suited.

Single-stage compressors are in common use in the smaller sizes and for the lower pressures. These are ordinarily single-cylinder machines. Two-stage compressors are employed in the larger capacities and for the higher pressures. These are commonly duplex machines with cranks 90 deg. apart. Single-stage compression is properly employed for gage pressures up to 60 lb. per sq. in. For pressures from 60 to 100 lb. per sq. in. the selection of the compressor

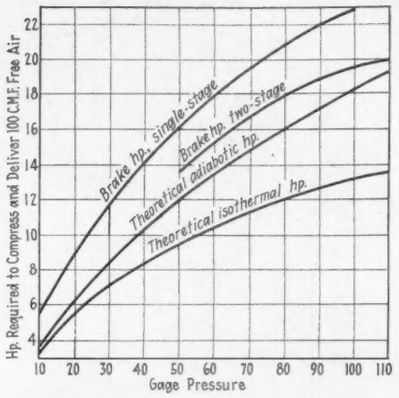
should be governed by the capacity, the altitude, and the cost of power. For discharge pressures above 100 lb. per sq. in., two-stage compressors are considered standard.

The compression of air develops heat. As the air cools before being used, this heat is lost and leads to shrinkage of the air compressed. If air is compressed adiabatically, that is, with no cooling during compression, more power is required than if the air were compressed isothermally, that is with sufficiently cooling to maintain constant temperature through the compression operation. However, it is not possible to accomplish isothermal compression. As an approach to this condition, water jackets on the compression cylinders are employed, together with multi-stage compression having inter-cooling coils between stages.

For the reasons just stated, two-stage compression is materially more efficient than single-stage compression. The difference is more pronounced the higher the ratio of compression. For pressures above 60 lb. per sq. in. two-stage compression is preferable. In case of high altitudes the ratio of compression is increased and the benefit of two-stage compression is enhanced. The higher efficiency of the two-stage machine lowers the power consumption, which may permit the use of a smaller motor. The saving in motor cost resulting thereby, may partially offset the higher cost of a two-stage compressor. Two-stage compression is generally to be preferred for pressures of 100 lb. and above with displacements of 300 cu. ft. of free air per min. and above.

Power Required to Drive Reciprocating Air Compressors

The power required to drive a reciprocating air compressor depends upon the size, type, ratio of compression and many design details. Average conservative values of brake horsepower at the compressor shaft per 100 cu. ft. per min. of free air delivered, are given both for single-stage and two-stage compressors in the diagram on this page. This diagram also shows the theoretical power requirements for adiabatic as well as for isothermal compression. The overall efficiency of commercial single-stage compressors, referred to isothermal compression is on the order of 60 per cent. The over-all efficiency of two-stage compressors is more nearly 65 to 70 per cent. In the case of belt-driven compressors some allowance should be made for belt losses in arriving at the horsepower required at the shaft of the motor.


Hp. Required to Compress and Deliver 100 C.M.F. Free Air
Brake hp., single-stage
Brake hp., two-stage
Theoretical adiabatic hp.
Theoretical isothermal hp.
Gage Pressure
10 20 30 40 50 60 70 80 90 100 110
4 6 8 10 12 14 16 18 20 22

Brake horsepower required at compressor shaft per 100 cu. ft. of free air per min.

Values are given for both single-stage and two-stage compressors for gage pressures from 10 to 110 lb. per sq. in. Comparative adiabatic and isothermal compression power requirement curves are shown.

The values shown in the diagram on this page refer to sea level conditions. In the case of high altitudes the ratio of compression and the mean effective pressure are increased and the power required per cu. ft. of free air per min. is greater. However, the capacity of a given compressor is reduced to a greater degree than the increase in unit power requirement. Therefore, an equipment which is correct under sea level conditions may be overmotored at high altitudes. The table on page 15 shows the corrections to be made for altitude. The factors given in the last column of the table should be used in correcting the curves in the diagram on page 14 so as to make allowance for different altitudes.

The power consumption of compressed air systems may be seriously affected by leakage. To avoid excessive power wastage from this cause it is desirable that the tightness of the air lines be tested frequently by noting the rate of drop in pressure when all legitimate uses of air are temporarily discontinued.

The reciprocating compressor, a positive displacement machine, delivers a definite quantity per revolution. It is thus possible to vary the delivery by changing the speed. In this case the torque maintains a definite value and the horsepower required increases directly with the speed. With steam engine drive the speed is commonly varied to give the delivery required.

It is usually desirable to drive air compressors by alternating-current motors because, (1) power is generally available in this form and is cheaper, (2) avoidance of conversion loss, (3) fairly large amounts of power are commonly involved, and (4) because alternating-current motors are excellently suited to the work. As the alternating-current motor is inherently a constant-speed machine several methods have been

A short-center belt drive gives a very flexible and economical arrangement.

This Ingersoll-Rand two-stage, air compressor is driven by a wound-rotor induction motor. A manually-operated drum controller, as shown at the left is used for starting.

developed to vary the delivery of compressors driven at constant speed, in order to adjust the output to the demand.

Methods of Taking Care of Irregular Air Demand

Where the demand is irregular but not intermittent it is best to "unload" the compressor during periods of light demand. There are several methods of unloading. In one method the admission of air is prevented and the piston is operated in a partial vacuum. However, with this method the transition from no-load to full-load may be rather sudden. To avoid this another method used prevents the admission of air and opens the discharge valves of the compressor. In the third method, the suction valves are held open during both the suction and compression strokes.

An air compressor while operating "unloaded" requires about 15 per cent of its full-load input, which represents a considerable loss of energy. Light load operation over long periods is undesirable for this reason and also because of the low power factor resulting when induction motor drive is used.

Air compressors are now available which do not unload entirely and suddenly, but partially, by steps. These can be operated steadily at partial output, if desired, rather than intermittently unloaded or with full output. The more common method of providing partial unloading is by means of variable clearance regulation in which auxiliary valves open auxiliary clearance pockets. Other methods of partial unloading are by variable compression volume and variable suction volume. Partial unloading gives a more uniform motor load and may lower the power demand peaks where demand is determined on a two- or three-minute interval. Where demand is determined by an integrated consumption over fifteen minutes or more, partial unloading will not decrease the demand.

Where the demand is highly intermittent, it is not desirable to operate a compressor unloaded for long periods. It is then best to arrange for the motor to start and stop, as required, to maintain the pressure within limits in a storage receiver. Automatic magnetic control in connection with a pressure gage governs the motor operation. The illustration on page 16 shows such a method of control in use on a two-stage tandem compressor.

In air-compressor applications where a system is operated in this manner it is necessary that there be little leakage; otherwise the compressor will be called upon to operate from time to time when no air is being used, merely to supply the leakage. It is quite feasible to store a large supply of air in a receiver, the latter serving primarily to prevent too frequent starting and stopping of the compressor due to leakage in connection with a piping system of small volume.

Some compressors are installed under conditions where the demand for air may be highly intermittent during portions of the time and fairly heavy during other portions. It is not desirable to operate by the automatic start and stop method if the demand is such that the compressor is thereby started and stopped too frequently. It is often feasible to provide the compressor with unloading devices and also to arrange the control for automatic start and stop operation. Means may be readily provided for by-passing or cutting out either system. The compressor may then be operated with the unloading device during periods of heavy demand while the automatic start and stop system may be employed during long periods of light demand.

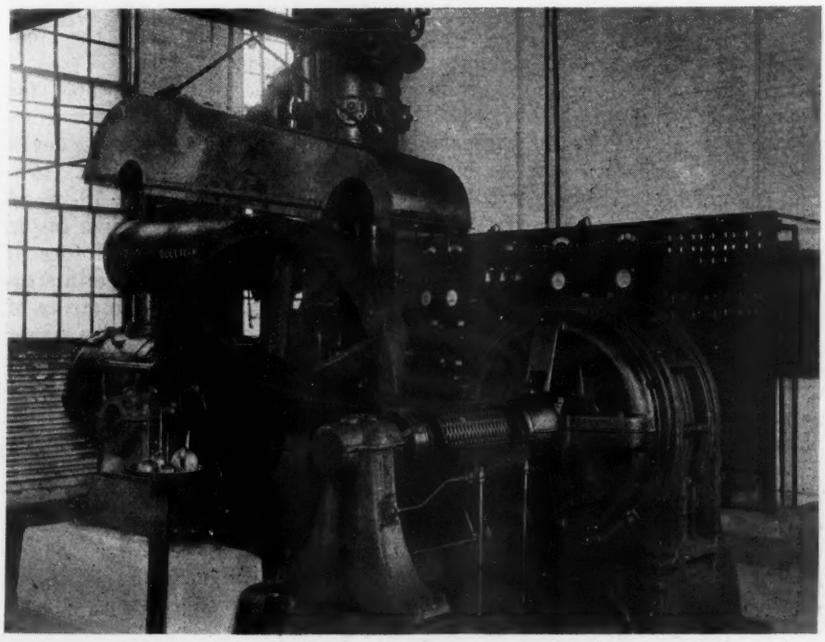
Motors driving air compressors equipped with unloading devices are limited as to loading and, therefore, require no overload capacity. Hence, drives of this type may be closely motored.

The rotative speed of a compressor is limited by the permissible linear speed of piston travel, which ranges from 300 to 550 ft. per min. The older compressors, suited for engine drive, commonly operated at low rotative speeds and had a long

Correction in Power Requirements of Air Compressors Due to Change in Altitude

Altitude Above Sea Level Ft.	Barometer In.	Inlet Air Pressure Lb.	Per Cent of Sea Level Delivery	Loss of Capacity Per Cent	Decrease in Power Required Per Cent	Increase in Power per 100 c. f. m. Per Cent
0	30.0	14.7	100	0	0.0	0.0
1,000	28.9	14.2	97	3	1.8	1.1
2,000	27.8	13.7	93	7	3.5	3.9
3,000	26.8	13.2	90	10	5.2	5.2
4,000	25.8	12.7	87	13	6.9	7.0
5,000	24.8	12.2	84	16	8.5	9.0
6,000	23.9	11.7	81	19	10.1	11.0
8,000	22.1	10.9	76	24	13.1	14.5

A silent-chain drive offers many advantages for connecting the motor to the air compressor.
In this illustration a Link-Belt silent chain connects a squirrel-cage motor to the compressor crankshaft. The top half of the guard has been removed to permit inspection of the chain.



stroke. Higher-speed, short-stroke machines are, in general, better suited for direct connection to motors. Air compressors of large capacity are now standard at speeds around 200 r.p.m. and smaller machines at speeds of 300 r.p.m. and above. These relatively high speeds reduce the initial cost of the compressor and drive, increase the efficiency, and simplify the provision of flywheel effect.

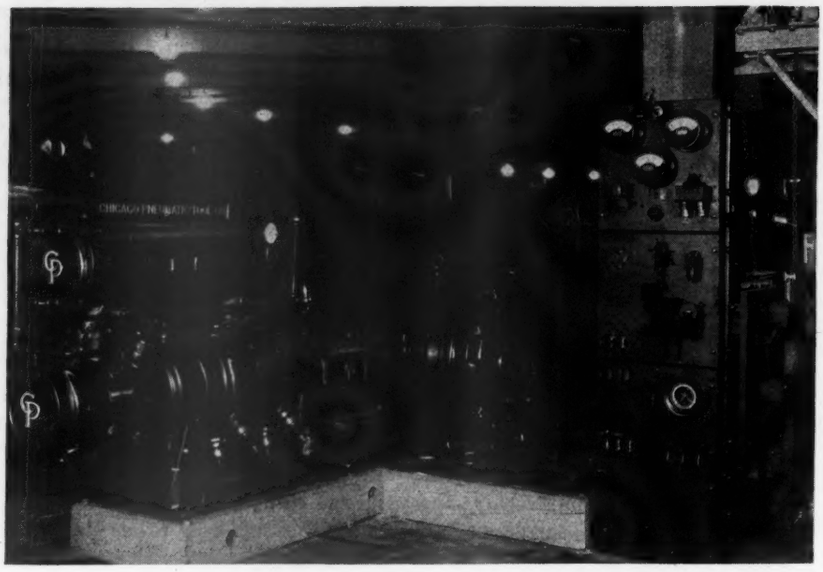
Selection of Type of Motor and Drive Connection

The synchronous motor is preeminently adapted for the great majority of air compressor drives. Except for some of the smaller units, direct-connected motors are desirable, primarily because of economy of floor space and elimination of intermediate drive mechanism. The induction motor is not commonly built for such low speeds, for at such speeds this type of motor has the disadvantages of both low efficiency and low power factor.

On the other hand, the low-speed synchronous motor is highly efficient and affords a high power factor, which is subject to control. The synchronous motor retains a good efficiency at partial loads. If excited for unity power factor at full load, the power factor will be slightly leading when the compressor runs unloaded. For the unusual, constant-speed, continuous-running duty the synchronous motor is ideal. The starting requirements can be satisfactorily met. The wide air gap of this type of motor is favorable to engine-type construction. The cost of a low-speed synchronous motor is ordinarily less than that of an equivalent induction motor. The synchronous motor is so well suited in all respects that it is almost the unanimous choice for all direct-connected air compressors and for all compressors of large capacity.

The illustration on page 13 shows a typical installation comprising an engine-type synchronous motor with belted exciter, driving an angle compound compressor. Manual switching is required for starting, however, as may be seen from inspection of the control panel at the right.

The motor may be direct connected to the compressor by pressing the rotor onto the compressor shaft, as is shown in the illustrations on pages 16 and 17 or by connecting to the compressor shaft by means of rigid couplings.



Automatic start and stop from pressure gage control is used on many compressors.
This two-stage, tandem, Chicago Pneumatic Tool compressor is driven by a synchronous motor and controlled by the automatic panel shown at the right. The rotor of the synchronous motor is mounted directly on the crankshaft thus requiring no outboard bearing.

Air compressors of small capacity, notably those of the single-stage type are more commonly belt driven by induction motors. For the sake of space economy the short belt drive with idler pulley is generally employed. An installation of this type is illustrated on page 13. These motors may be either of the squirrel-cage or the wound-rotor type. For continuous - running service the squirrel-cage motor is quite satisfactory, particularly for the smaller machines. For "start and stop" service the wound-rotor motor is to be recommended.

On some types the motor is mounted on the end of the shaft as illustrated on pages 16 and 17. This does away with the need of outboard bearings. The motor may be built into the flywheel as shown at bottom of page 17. This does away not only with the outboard bearings but also with the separate stator bedplate.

A silent chain drive is often used for connecting the air compressor to its motor. Such a drive gives very good economy and flexibility in arrangement of floor space, combined with high efficiency and reliability. In selecting silent chains for air compressor service, it is usual to choose one having a rating of 120 per cent of the motor capacity. A silent chain drive for an air compressor is illustrated on page 15.

Where belt or chain drive is employed there is sometimes an advantage in adjusting the compressor speed and capacity to suit the motor rating. Consider a machine rated at 300 cu. ft. of free air per min. at 240 r.p.m. and requiring 80 hp. If this machine were operated at 225 r.p.m., its capacity would be reduced to 281 cu. ft. per min. and a 75-hp. motor would suffice. On the other hand, if a 100-hp. motor were used, the compressor speed might be increased to, say, 280 r.p.m. (if allowable) and the capacity increased to 350 cu. ft. per min.

Changing the compressor speed by changing the size of motor pulleys may bring the output of the compressor more nearly in line with the demand for air and thereby prevent frequent starting and stopping of the compressor or prevent long periods of operation with the compressor unloaded.

Synchronous motors suitable for direct connection to small air compressors have been recently developed. A 40-hp., 300-r.p.m. synchronous motor driving a 10-in. by 8-in. air compressor is shown in top illustration on page 17. Motors of the type shown are available in sizes down to 20 hp. They offer many of the advantages common to the larger machines, although in lesser degree. For continuous-duty, permanent installations their use is particularly warranted.

Very few large air compressors are driven by direct-current motors. They are sometimes used for medium and small size machines. These installations are generally of the belt drive type, but engine-type, direct-

current motors may be successfully employed where only direct-current power is available. Compound-wound motors are generally preferred, primarily because of their better starting capacity and also because they are more adapted to a load requiring a pulsating torque combined with high inertia.

Effect of Pulsating Torque on Motor Selection

The torque required for driving a reciprocating compressor is irregular, having pulsations due to varying crank effort. A synchronous motor inherently tends to hold constant speed and varies its torque with the slight changes in angular velocity resulting from the varying load torque. This results in a periodic variation in power input. The amount of angular speed variation depends upon the load-torque variation and the inertia of the revolving parts. It is commonly necessary to adjust the flywheel effect for two reasons: first, to prevent the combination of mechanical oscillations due to load and those oscillations due to varying motor torque in a manner to cause resonance and hunting; and second, to limit the extent of periodic current variation.

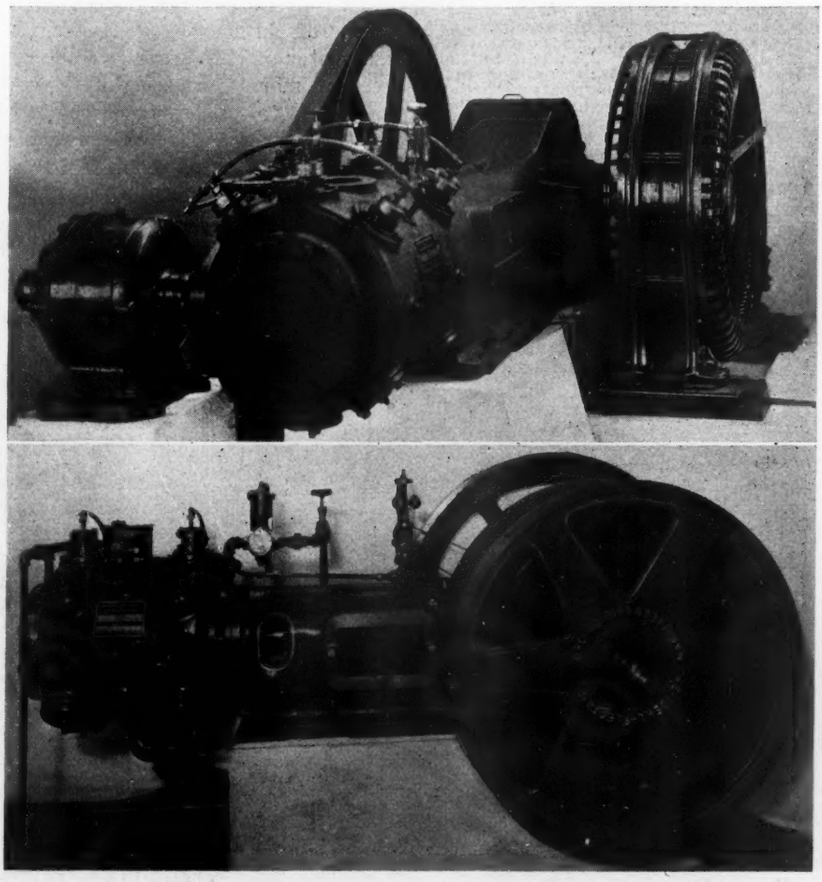
The Electric Power Club and the American Society of Refrigerating Engineers have adopted the following rule in regard to current variation in synchronous motors driving air and ammonia compressors:

"When the driven load, such as that of reciprocating pumps or compressors, requires a variable torque during each revolution, the combined installation shall have sufficient inertia in its rotating parts to limit the variations in motor armature current to a value not exceeding 66 per cent of full-load current.

"The basis of determining this variation shall be by oscillograph measurement and not by ammeter readings. A line shall be drawn on the oscillogram through the consecutive peaks of the current wave. The variation is the difference between the maximum and minimum ordinates of this envelope. This variation shall not exceed 66 per cent of the maximum value of the rated full-load current of the motor. (The maximum value of the motor armature current is to be assumed as 1.41 times the rated full-load current)."

This rule does not necessarily determine the proper practice in all cases. It is sometimes very difficult to supply sufficient flywheel effect to restrict the current variation within the limits above stated, in which case a greater variation may be permissible. In other cases it may be desirable to restrict the current variation to as low as 25 per cent of rated full-load current.

So far as the motor is concerned, a somewhat greater variation than 66 per cent ordinarily has very little effect on performance, reliability, heating, and efficiency of the motor. The matter is largely one involving the effect on the supply system. Where lighting supply is involved a low current variation is desirable. On lines devoted exclusively to power supply, larger variations are not detrimental.



Two types of synchronous motors in use on single-stage compressors. In the top illustration, the rotor of the motor is pressed directly on to a short extension of the crankshaft, thereby eliminating the necessity of an outboard bearing. The stator is mounted on a separate bedplate, which makes a very accessible arrangement. In the bottom illustration is shown a synchronous motor that is built into the flywheel of the compressor. The rotor is on the outside of the stationary element, the fields being attached to the flywheel. The stator winding and core is concentric to the fields and is attached to the compressor frame. This arrangement does away with the necessity of a separate bedplate for the motor, lightens the compressor weight and yet is very accessible for repairs or maintenance. Both compressors shown in these illustrations are single stage and are made by the Chicago Pneumatic Tool Co., New York, N. Y.

Starting Requirements of an Air Compressor Drive

With two-stage, duplex compressors, it is not ordinarily difficult to supply sufficient flywheel effect to prevent resonance and to restrict the current variation. In some cases the necessary flywheel effect is included in the revolving member of the motor. This practice is open to question if the decrease in effective diameter requires a material increase in weight. Not infrequently it occurs that widely differing values of flywheel effect will meet the requirements, in which case the lowest value may well be used, thereby minimizing both the first cost and the inevitable bearing losses. With straight line compressors it may be more difficult to meet flywheel requirements, due to the greater variation of load torque. For a further discussion of flywheels for synchronous motors see page 451 of the "Principles of Electric Motors & Control" by the writer.

Air compressors, except in the smaller sizes, are ordinarily ar-

ranged to start unloaded. The torque required to start from rest is then 10 to 30 per cent of the full-load torque. A suitable synchronous motor can develop this torque with an input of 150 to 300 per cent of full-load kva., depending upon motor speed and design and the starting voltage. The size of the flywheel materially affects the starting requirements of a compressor drive.

Indirectly it decidedly affects the pull-in torque. As a large flywheel may have too much inertia to be pulled into step from say 95 per cent speed, it may be necessary to reach perhaps 97 or 98 per cent speed by induction motor action. It is much more difficult to obtain a high pull-in torque at 97 per cent speed because the induction-motor torque is nearly proportional to the slip and falls off as synchronism is approached.

Bearing friction influences the starting torque required. The inertia of the compressor affects the pull in torque demanded by making it necessary for the motor to approach more closely to synchronous speed by induction motor action, thereby reducing the speed range through which the flywheel must be accelerated at the instant of pull-in. Compressors with light flywheels require about 15 per cent full-load torque to pull into synchronism under unloaded conditions. Compressors with large flywheels may required 25 to 30 per cent pull-in torques.

Wound-Rotor Motor Best Adapted to Frequent Starting Duty

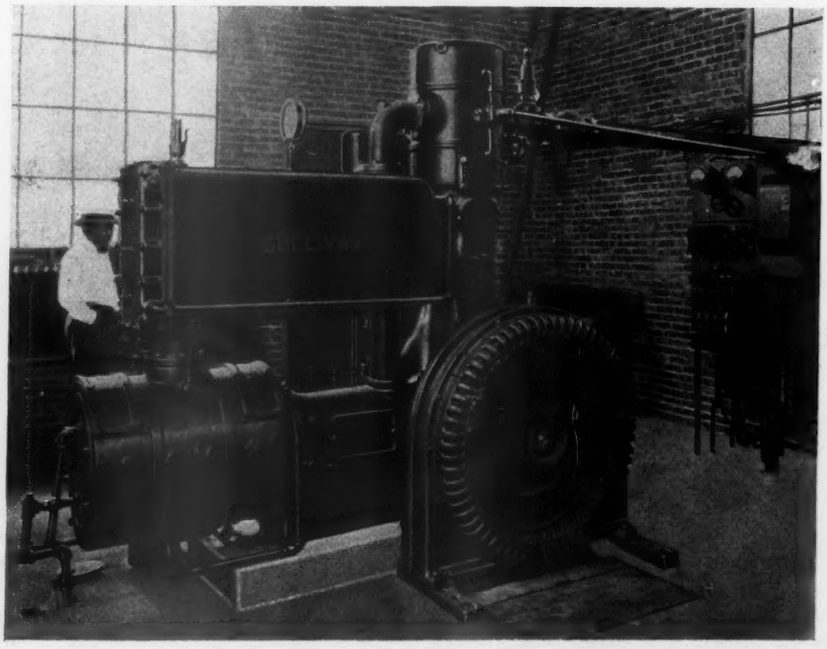
The synchronous motor is quite satisfactory in starting characteristics for driving air compressors which start only infrequently. It is superior, in many instances, to the squirrel-cage induction motor, since the cage winding of a synchronous motor may be designed with a view to starting requirements only. The wound-rotor induction motor is suitable for "start and stop" service, since the current inrush for a given torque development is low. Synchronous motors with automatic starters are used successfully for this service, however.

Unloading both at starting and stopping is desirable when belt drive is employed, especially with the short belt and idler pulley arrangement. If the compressor is unloaded at stopping it will drift smoothly to rest with the motor. If it is not unloaded, it may jerk the belt and pitch the idler pulley. Some compressors are equipped with a fly-ball device which unloads the compressor when it is running at speeds materially below normal. Some compressors are now equipped with a small electric solenoid which operates small air valves, functioning indirectly to cause unloading. This solenoid is connected so as to be energized by the last operation of the motor control panel, during acceleration, thus causing the compressor to load as the motor attains speed. When power is cut off to stop the compressor, the solenoid drops and immediately causes unloading. In the case of "start and stop" units a cooling water valve is sometimes included in the automatic system to prevent wastage of water when the compressor is idle and vice versa. Where the solenoid unloader is employed it may well be energized from the transformer which supplies the magnetic contactors, but a small increase in the capacity of this transformer may be necessary.

Direct-connected compressors should preferably run "under." A belted compressor may have to run "over" so as to have the slack belt side on top thereby increasing the arc of contact between belt and pulleys.

Push-button control offers many advantages for starting synchronous motors.

This angle compound Sullivan Machinery Co., air compressor is driven by a synchronous motor that is started by means of magnet-operated, air-break contactors as shown on the panel at the right of the illustration. A push button causes the control to function and the motor is automatically started, brought up to speed, field applied, and put on the line without any attention from the operator, thereby permitting the use of oilers and unskilled labor for this duty. As may be noticed, this motor requires no outboard bearing.



Correcting Power Factor by Air Compressor Motor

In selecting a synchronous motor for driving a compressor, a choice is necessary between the machine which is rated on a unity power factor basis and the machine rated, usually, on an 80 per cent power factor basis, for power factor correction. This point is affected largely by local considerations involving the need of power factor correction and the savings to be made thereby. A unity power factor installation may cause considerable improvement in plant power factor especially in view of the fact that the power factor will be leading when the compressor runs unloaded. A leading power factor motor will not be justified unless sufficient advantage can be realized, through its corrective qualities, to outweigh its higher first cost and lower efficiency. The efficiency at 80 per cent power factor leading will normally be 2 or 3 points below the efficiency that would be obtained at unity power factor.

Due to the greater synchonizing power of the over-excited synchronous motor used for power factor correction, more flywheel effect may be required to restrict the current fluctuation. This may be inherent in the larger frame required for the over-excited machine.

Fig. 1—This lineshaft installation in one of the Chicago plants of the Continental Can Co. is supported by special steel shapes designed for such work.

In this case short inserts were cast in the concrete ceiling beams. Sections of stringers are bolted to these inserts and a longitudinal pair of stringers, which is bolted to these, forms the footings for attaching the hangers. The lineshaft may be easily shifted a few inches or feet by loosening the bolts which hold the two longitudinal stringers and sliding them in either direction. Also, the entire installation may be taken down and re-erected in any part of the building and all of the groundwork re-used without any waste or cutting except when necessary to provide for a change in length of the shaft. The entire building is provided with inserts in the ceiling beams on 4-ft. centers. This is of great importance in the rapid shifting of machinery and departments.

Methods of

Using Steel Forms for Supporting Lineshafting

in mill type, steel and concrete buildings in order to reduce the work of erecting this equipment and to facilitate future changes in layout

By P. L. PRYIBIL

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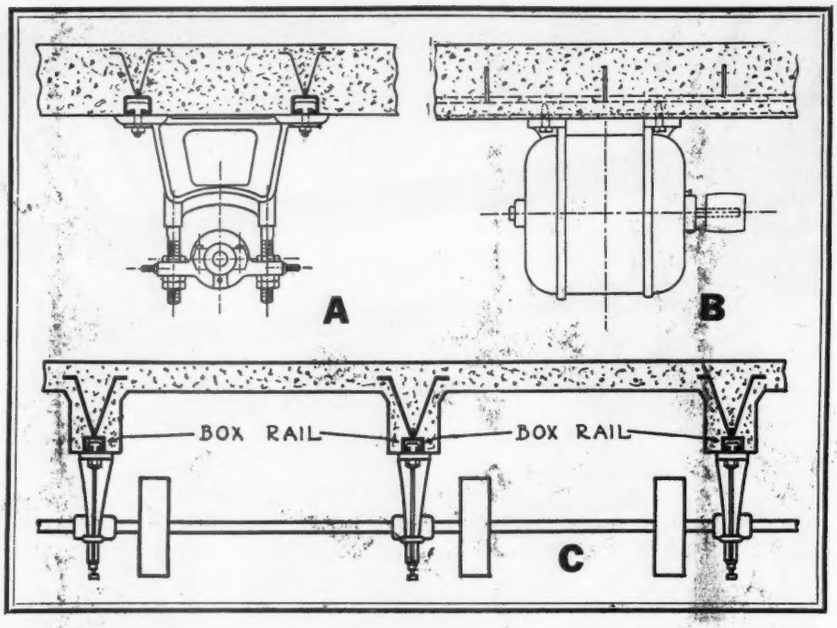
MANY unusual conditions are encountered by the erection superintendent or the millwright when installing lineshafts, especially where the groundwork has to be devised and placed in position. This kind of work as a whole is more diversified than one who is not initiated would imagine and the physical layout and conditions within factory buildings offer very trying problems at times. The competent millwright or erecting engineer who has to solve them is worth all one has to pay him and often more.

For this reason, a discussion of the problems invoked in erecting lineshafts in the different types of industrial buildings in use, with particular attention to the lack of provisions for easy anchorage of mechanical equipment, may be helpful to the readers of INDUSTRIAL ENGINEER, many of whom have to solve problems of this nature. In this article, particular attention is directed toward the remedies which can be provided to partially eliminate these adverse conditions, in so far as the building itself is concerned, or to compensate for them through the use of standardized appliances perfected after many years of experience in erecting lineshafts and supporting various other machinery overhead in industrial plants.

The supporting of lineshafts and countershafts, as well as motors and other power transmission apparatus, in buildings used for manufacturing purposes is nearly always more expensive than the initial estimates indicate and frequently is more difficult than was anticipated when making the plans for the installation. Two of the fundamental reasons for this are the differences in



Figs. 2A, 2B and 2C—Here long box rails are cast in the ceiling, instead of short inserts as in Fig. 1.

These Midwest box rails are of a special shape to take a bolt head and are cast in the concrete ceiling. The equipment or machinery may be supported directly from them as shown in these three illustrations. However, in installations such as *A* and *B* where parallel box rails are cast in the ceiling at the proper distance apart to take a lineshaft hanger or motor footing, there is no opportunity of moving the shafting to one side or other. It is generally much more advisable to set these inserts in the beams, as at *C*, or at fixed centers and attach stringers or cross rails as in Fig. 1.

the styles and types of construction of buildings used for manufacturing purposes, and to the lack of standardized forms or shapes for fabricating the superstructure or groundwork for the direct attachment of lineshaft hangers. The differences in types of buildings apply not only to buildings especially designed for manufacturing but also to converted buildings, such as structures originally built for warehousing or for innumerable other uses, and which are ultimately, with or without alterations, fitted up with machinery and used for manufacturing.

Under the best conditions, that is, where a building is constructed for a particular manufacturing problem or industry and the type of machinery which is to be installed is known, there are still many different types of building construction. One of the most common is the so-called mill construction type; other types are, brick buildings with wood interior, brick and steel buildings, concrete buildings, and some all-steel buildings with steel framework and sheet-metal walls, roofs, and partitions. Nearly all of these are built in multi- as well as single-story designs, except the brick and steel building with saw-tooth or monitor roof. Some multi-story buildings have saw-tooth or monitor roofs on the top floors. Single-story structures are practically always built for owner occupancy, irrespective of what type of construction is used, and so better plans can be made for the installation of the machinery. Multi-story buildings are frequently built for tenant occupancy, to be rented out to one or to a number of concerns for a variety of manufacturing purposes.

The loft buildings in the outskirts or in industrial sections of large cities are typical of the type of building erected for renting to a number of concerns. In buildings of this type it is, of course, impossible to know in advance what kind of equipment will be used by the different tenants, and even if it could be known in the case of the first tenant any provision which might be made for him would seldom be suitable for subsequent tenants in the same space.

Many large firms in this country have made it a practice when building warehouses, particularly in the large cities, to erect a factory-type building and make provisions for using it for manufacturing in the future. Experience has demonstrated that such forethought is necessary, as well as advantageous.

All these different conditions and different types of buildings and the various kinds of equipment to go into them have made it very difficult for the architect, the industrial or plant engineer, and last, but by not least in this instance, the millwright, to work along predetermined lines in providing for the location and support of lineshafting and similar equipment.

Fig. 3—Box rails are set both longitudinally and crosswise in the ceiling beams of this concrete factory building.

This shows the method of erecting a lineshaft by providing a cross stringer between two parallel rails and attaching the footings of the hangers to these. If the lineshaft had been extended crosswise in this room the construction shown in Fig. 2*C*, could have been used.

Until recent years wood has been a popular material for making supports in the form of footings, stringers and for the framework and body of superstructures. In fact, in some parts of the country, timber has been used almost exclusively. Wood is adaptable for such purposes, but only to a limited degree, and it is not flexible nor interchangeable. It can be cut to desired lengths and widths, it can be notched and drilled to receive bolts and lagscrews, but this is always a cut-and-measure proposition, involving a certain amount of carpenter and millwright work. Although, when finished, the component parts may resolve themselves into a more or less practical and harmonious whole, the resultant truss or framework will be suited only to the particular position and installation for which it was fabricated.

Rarely can the same layout be used to suit another condition; of course, the material itself can be recut and reformed and some of it used over again, but the framework for intermediate supports usually has to be redesigned for each particular case. However, in spite of its main advantage, which is that it is comparatively easy to work, wood has a very distinct disadvantage in its susceptibility to changes in temperature and its inherent tendency to dry out which causes it to shrink, warp and twist constantly and sometimes for many years after it has been installed.

This characteristic is the chief cause of trouble where wood is used to support overhead equipment and is responsible for much of the consequent misalignment of lineshafting and motors, which causes belting troubles and bearing replacements all along the line down to the last production or operating unit. Wood which is suitable for this groundwork for shafting, is comparatively cheap, especially in certain geographical locations, but the troubles so frequently caused by its shrinking often in the end offset the apparent saving in first cost.

When heavy loads and long spans have to be contended with, as for instance in brick and steel buildings where the bottom chords of the roof trusses are from 18 ft. to 24 ft. from center to center, timbers of large cross-section have to be used; such stringers are often 8-in. by 12-in., or even 10-in. by 14-in., and impose a serious additional load upon the roof trusses. It is because of the live load and the impact to which the lineshaft is subjected, as well as to minimize the deflection, that such heavy timbers have to be used. Because of their weight these members are much more costly than structural or other metal stringers and they cost more to handle as they require expensive rigging to erect.

In many cases, as outlined above, wooden stringers are not always dependable even after they are installed. The millwright is well aware of all these deficiencies, but is not always in a position to dictate the remedies. On a heavy headshaft hanger or post hanger he will often put a square steel washer between the hanger foot and the wood stringer. By this means he is endeavoring to secure a firm, even base for his hanger foot to offset the effects of vibration and thereby maintain permanent alignment of his lineshaft and of all the other driven units which depend upon proper alignment for their satisfactory functioning. However, the use of wood for such purposes, in a steel or concrete building, or in any kind of fireproof building, is decidedly inconsistent.

Standard structural steel members and shapes have been used very satisfactorily for constructing groundwork and as stringers for lineshafting. These are lighter than wood for large spans and they are susceptible to much greater flexibility of arrangement. However, structural steel is hard to cut, drill, and form in the field. Furthermore, standard structural steel shapes are not primarily designed for this purpose and as a natural consequence special fixtures become necessary and channels or I-beams have to be used, which in many instances, are heavier than necessary. This extra weight is an additional expense, not only because it is paid for by the pound but also because of the extra labor in handling the heavier weights on the job. The cost of cartage and railroad transportation is also on a weight basis. In addition, as when heavy wooden stringers are used, there is the extra deadweight load on the ceiling or roof trusses.

Cutting, punching and the general fabrication of standard steel shapes is comparatively easy in steel mills or fabricating shops, but in order to have this work done there and to insure its fitting properly and matching up to the members to

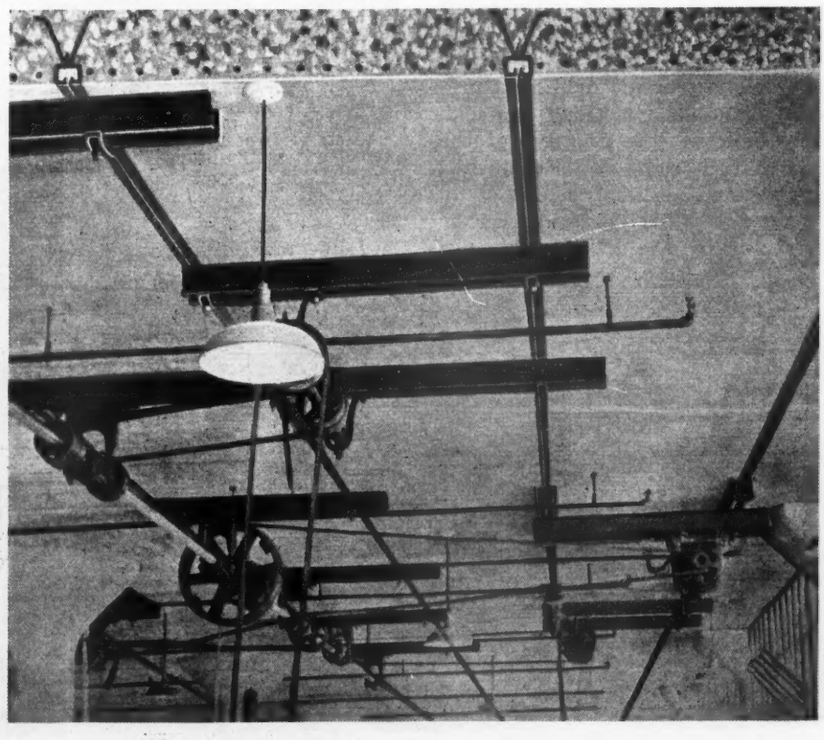


Fig. 4—Part of a lineshaft installation in the Saco-Lowell Shops, Boston, Mass.

This photograph was retouched at the top to show the construction of the box rail in the ceiling and its reinforcing. These box rails are set in the concrete on fixed centers. The method of attaching the footings and groundwork for not only the lineshaft but additional countershafts and motor mountings is also shown.

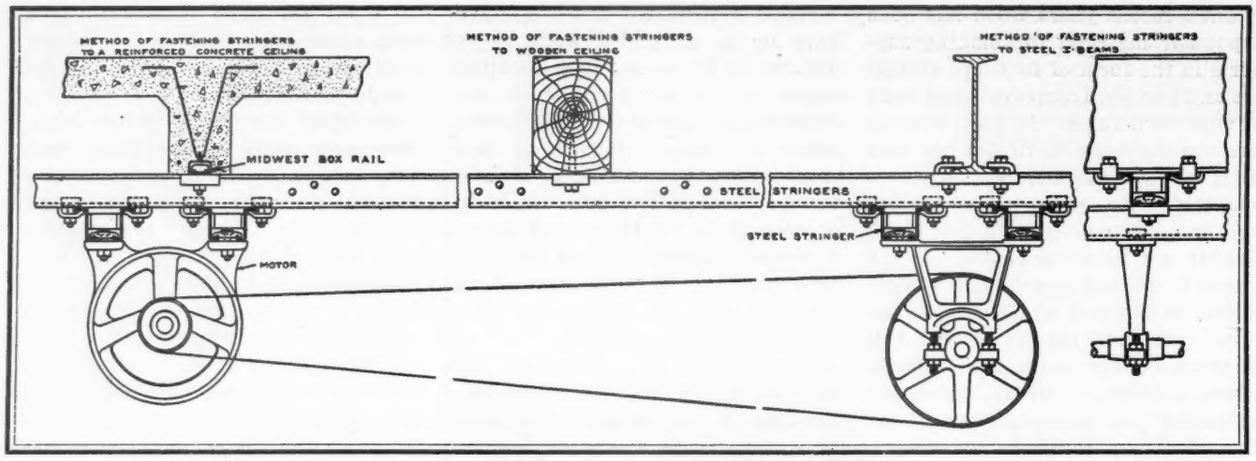

METHOD OF FASTENING STRINGERS TO A REINFORCED CONCRETE CEILING
METHOD OF FASTENING STRINGERS TO WOODEN CEILING
METHOD OF FASTENING STRINGERS TO STEEL I-BEAMS
MIDWEST BOX RAIL
STEEL STRINGERS
STEEL STRINGER
MOTOR

Fig. 5—This composite drawing shows three methods of construction for supporting lineshafts.

The method of fastening stringers to a reinforced concrete ceiling with the box rail cast in the beam, the method of fastening to wooden beam ceilings, and also to steel I-beams are shown in this drawing. These steel stringers are especially designed for this work and are made in standard sizes for different loading. The stringers and shafting are erected and fastened together with standard attachments.

which it has to be bolted in the building all dimensions and specifications must be exact. This requires a lot of work in the drafting room and in many cases cannot be started with safety until the building, or at least the steel framework, is finished. The new factory may be miles from a machine shop or even a hardware store, and when millwrights at a wage rate of anywhere from $9 to $14 a day have to cut through steel I-beams with a hand hacksaw or cold chisel, or support a heavy electric or air drill on a precarious scaffold, sometimes in a cold, damp building, the progress of the work is likely to be slow; meanwhile helpers and others often stand around and wait. If the power or air supply for the drill were always available, everybody would be happy; more often in the case of a new building, there is no current or air available either in the building or contiguous to it, and so the slow, old-fashioned method has to be pursued while somebody pays the modern up-to-date high rate of wages.

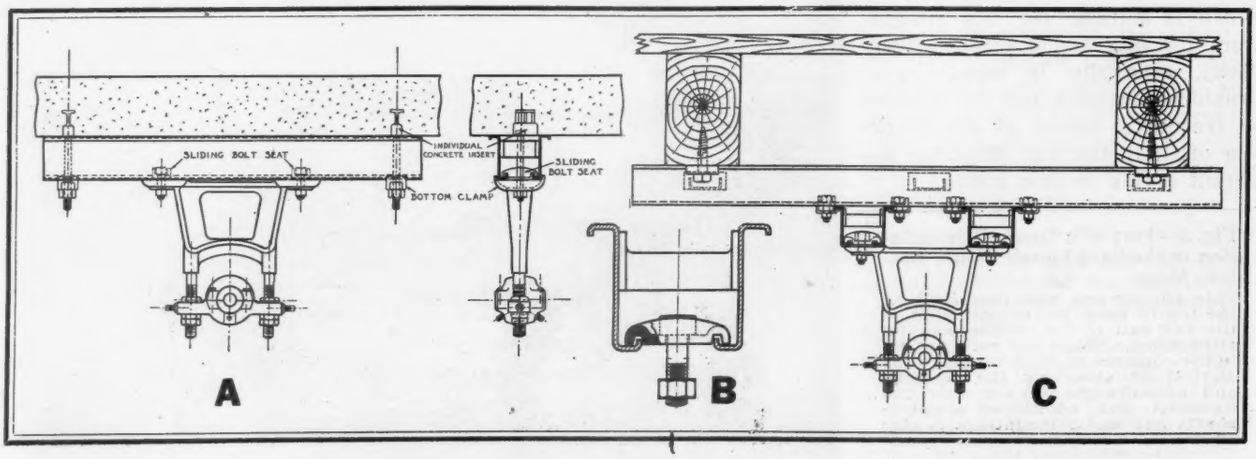
In arranging for the location of power transmission lines and equipment, the customer will often place his pencil on the blueprint before him, and say, "We'll just put our lineshaft here." It is so easily and quickly said, but what a deal of work and even ingenuity are sometimes involved in planning, measuring up for it, and in its installation. All things considered, the installation of a lineshaft, which is really the prime mover, generally proves to be a man-sized job, especially under the old methods.

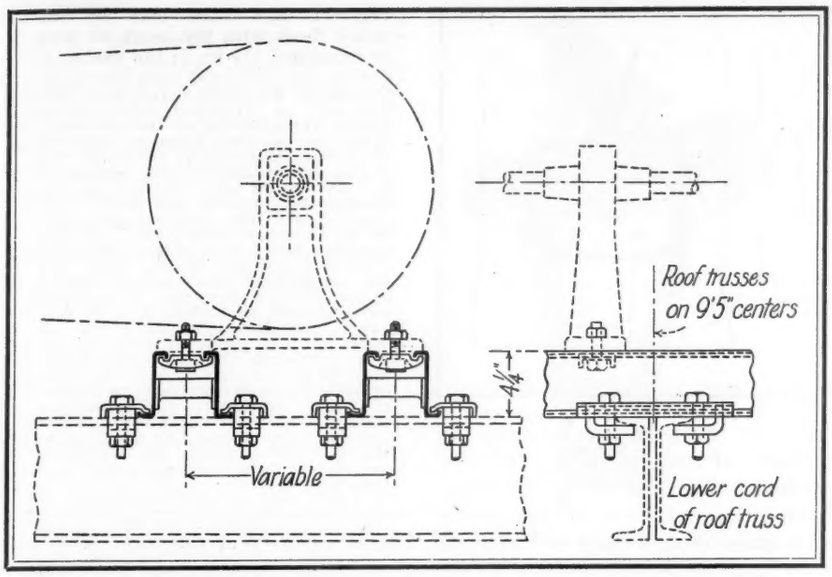
A good, substantial, wooden building with heavy beams and girders, and with broad trusses and columns of large sectional area, gives dependable supports for lineshaft hangers and largely simplifies the work of the millwright in erecting the lineshaft. The troubles incidental to drying out come later.

In concrete buildings the individual concrete insert, which is set in place in the form and the concrete poured around it, is a great help for supporting equipment. These inserts are usually dependable for ordinary lineshaft drives using shafting up to 1 15/16 in. in diameter. Such inserts are generally placed on 4-ft. centers, running in both directions. This saves much work in drilling holes for anchors

Figs. 6A, 6B and 6C—These show two other types of construction and also a cross-section of this special stringer.

In *A* is shown the method of installation where the hangers are supported midway between and on a line with ceiling inserts. As these inserts are usually on a 4-ft. center spacing and lineshaft hangers are commonly spaced 8-ft. this construction is usually possible. *C* shows the use of a short stringer between two wooden ceiling beams and the longer longitudinal stringers which give rigidity to the construction and to which the hangers are attached. A cross-section of the stringer, together with the detail of sliding bolt, is shown in *B*. This consists of two special steel shapes, somewhat on the order of the letter Z, which are fastened together by steel cross braces placed at regular intervals. Standard bolts and attachments permit these to be clamped easily to each other or to any other standard or special shape.





and patching them up again after the equipment is installed. Installations using this type of construction are shown as Figs. 1 and 9. Wood or steel stringers are suspended from two or more of these individual concrete inserts and lineshaft hangers or other overhead equipment attached to the stringers or footing pieces.

By referring to these two illustrations it is easily seen how a lineshaft can be placed anywhere between two lines of inserts by shifting the hangers without changing the groundwork. To move a line of shafting the entire construction can be taken down and erected again in the new location by attaching it to different lines of inserts. This is of especial importance in manufacturing institutions because a change in product or a wide variation in the quantity of production may require an extensive shifting of machine and lineshaft arrangement. This is more easily done if it is not necessary to again drill holes in the ceiling and refabricate the groundwork. With special steel stringers and inserts the shafts can be taken down and erected in the new location and frequently the same steel parts are reused in the new groundwork. This ability to reuse the material without additional fabrication goes far toward overcoming any difference in first cost of such material when compared to wood.

Fig. 7—This sketch shows how a standard construction can be used for a special purpose.

In this case it was necessary to attach a lineshaft to the top of a ceiling beam. To do this the same standard type of construction was used as would have been used if the attachment had been made on the bottom of the beam or if it had been made along an inside wall. This can be easily seen by turning the drawing over or revolving it 90 deg.

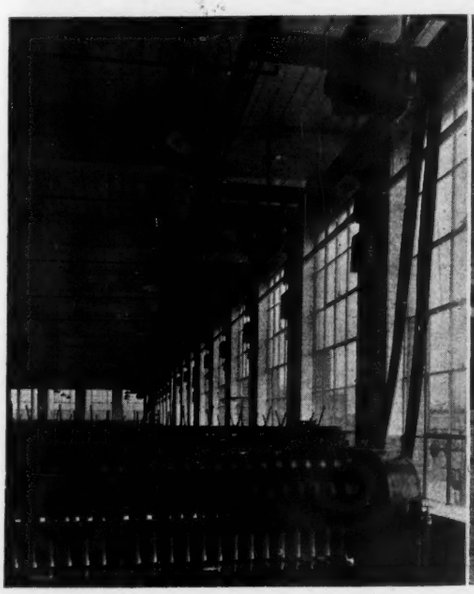
* * * *

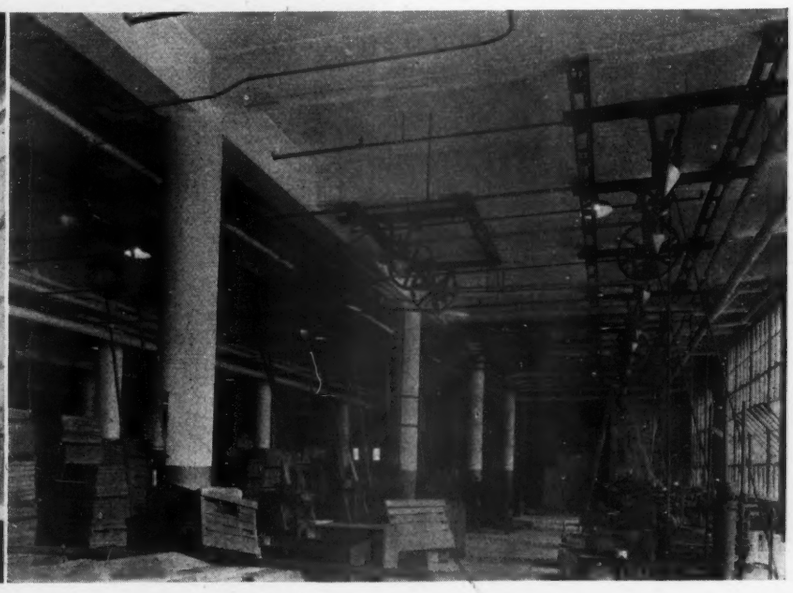
Figs. 8 and 9—Here is a neat-appearing method of mounting motors and lineshafts.

Fig. 8, at the left, shows the method of mounting 15 10-hp. motors in a line on the ceiling. The longitudinal stringers, that carry the short cross-footings to which the motors are attached, are clamped to the I-beam ceiling supports. This gives a simple construction which can be easily shifted to change the position of the motor or its arrangement. Fig. 9, right, shows another section of the installation in one of the Chicago plants of the Continental Can Co. Here inserts were cast in the ceiling beam (some of these can be seen in the first ceiling beam) for supporting the lineshafting.

A much better way to provide for light, as well as heavy shafting, in a concrete building is to use the long, continuous type of box rail insert. These inserts are attached to the wooden forms, before the concrete is poured, in the same manner as are the small individual inserts, but as they come in lengths of 5 to 20 ft., and may be obtained longer if necessary, they are much easier to handle, are less trouble to place, cannot be knocked over by the concrete when it is poured and, on account of their long length, insure proper alignment. When the concrete forms or molds are removed, a surface slot of steel is left in the concrete slab, the beams or the girders.

Figs. 2 to 5, inclusive, show diagrams of box rails as they were placed in the ceiling of two large plants, together with the method of attaching lineshafting and other power transmission appliances to them. As will be noted from these illustrations, the hollow steel box rail is cast in place and the surface slot which is flush with the concrete,





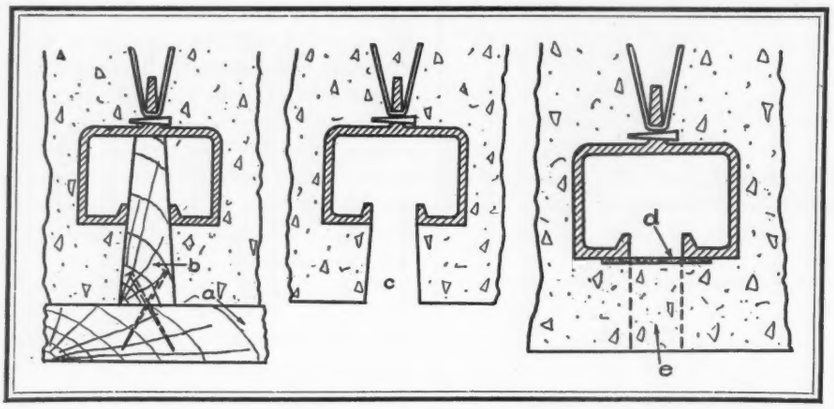


Fig. 11—Box rails may be set either flush with the beam or slab or imbedded 1½ in. in the concrete.

For simple imbedded rails the illustration at the left shows how the box rail is protected from filling during the pouring of the concrete. After the wooden form is removed the arrangement is as shown in the center illustration. For complete fire protection and where it is desirable to protect the box rails from fumes, the construction may be as shown at the right. In this case the box rail is supported away from the bottom of the form and the continuous slot in the bottom flange of the box rail is covered with a strip of roofing felt or felt paper, as shown at *d*, stuck on with roofing pitch or held on by wire. To use this box rail, holes may be cut or drilled into the concrete at the point where it is desired to place the bolt for attaching stringers or other equipment. After the bolts are placed and adjusted in the correct position the openings are filled with cement grout and thus sealed.

is immediately available for the attachment of the groundwork for lineshaft or other hangers. The box rail can be just as easily installed under or below the surface of the concrete, Fig. 11, if desired, so that the slot is still available without the rail being in evidence.

The installation of box rails does not weaken the concrete slab or member in any way but on the contrary acts as a reinforcing rod; as the box rail has a greater cross-sectional area than a bar 1 in. square, for instance, considerable additional reinforcement is provided. This continuous type of insert can be, and frequently is, laid horizontally or vertically in the walls as well as in the ceiling of concrete structures. Also, some large automobile plants have used them in the concrete floors for holding motors and for floor stands for lineshafts as well as for machines and other equipment. Incidentally the box rails are used in brick work as well as in concrete.

In developing the Midwest universal system for supporting overhead mechanical equipment it became increasingly obvious as the work progressed that it would be as necessary to provide for changes in equipment location as to work out the "where and how" of originally installing it. Complete changes in production processes and other radical departures from the regular order of work occur in the plant occasionally on account of taking on a different product. The resultant modifications in the nature of the operations may make it necessary to equip, at least in some departments, with entirely different kinds of production units. These and other difficulties were taken into account in the development of special steel stringers.

These stringers can be used for supporting any kind of lineshaft in any kind of factory building. A few interchangeable clips provide for attaching the stringers to all types of structural steel members, and to wood or concrete ceilings or side walls where individual inserts or box rails have been provided. No drilling of holes in the stringers is necessary; they are merely clipped into place with standard square- or hexagonal-head bolts. Special tools or fixtures are not necessary; an ordinary wrench is used for tightening the nuts on the bolts.

If changes become necessary for alignment, repositioning or moving the stringer to a different location the nuts are loosened and the stringers tapped over or completely shifted several feet. By means of the sliding bolt seat the shaft hangers or other equipment can be moved the full length of the stringer without encountering any obstructions. Advantage can be taken of this feature to facilitate tightening slack belts from lineshafts to countershafts and so eliminating the necessity for cutting and relacing.

Fig. 5 is a composite diagram showing how standard steel stringers may be attached to wood, concrete and steel construction buildings. The clips and clamps used are of standard construction and may be purchased with the stringer. Figs. 3, 4, 6*A* and 9, show applications of steel stringers on concrete flat slab and on concrete beam and girder buildings. When the stringers

Fig. 10—Standard 10-in. channels in pairs are used as stringers.

The illustration shows a section of the repair and maintenance shops of the Interborough Rapid Transit Co., New York City. Standard 10-in. channels, braced together in pairs, are clipped to the ceiling beams and are used as stringers for supporting the 300-ft. lineshaft. The feet of the hangers are attached to short cross-stringers as shown. This entire structure was fabricated in sections and erected by bolting together and to the ceiling I-beams with standard bolts, clips and clamps and can be moved and re-erected easily.

are used on wooden beams or trusses, Fig. 6*C*, lagscrews are used.

Steel stringers can be easily clipped together at right angles to each other, as shown in Figs. 5 and 6*C*. This adds greatly to the flexibility of the system and is especially handy where top stringers are used as groundwork and where odd-sized hangers are used, or where motors of different sizes are installed.

To take advantage of all available headroom a lineshaft is sometimes placed on top instead of on the bottom of the roof beams, as shown in Fig. 7. This illustration is from a drawing of an actual installation. If the drawing is turned upside down, which would be the same as mounting the equipment on the bottom of the stringer, the relation of the stringers and all fastening parts would be the same for the reversed installation. If the drawing or installation is turned 90 deg. the relation of all parts would still be the same; such an installation as this occurs where the lineshaft is erected on columns down the center or along the side wall of the building.

Part of an installation of electric motors mounted overhead on the steel ceiling beams in one of the large yarn mills of Wm. Crabtree & Sons, Newburgh, N. Y., is shown in Fig. 8. The use of steel stringers makes a neat-appearing installation. Steel stringers like these are used for all lineshafting construction throughout this Company's plants.

The method of supporting lineshafts at the plants of the Continental Can Co., Chicago, Ill., is shown in Figs. 1 and 9. Box rails and steel stringers are also used in these plants for supporting conveyor systems on a large scale, Fig. 14.

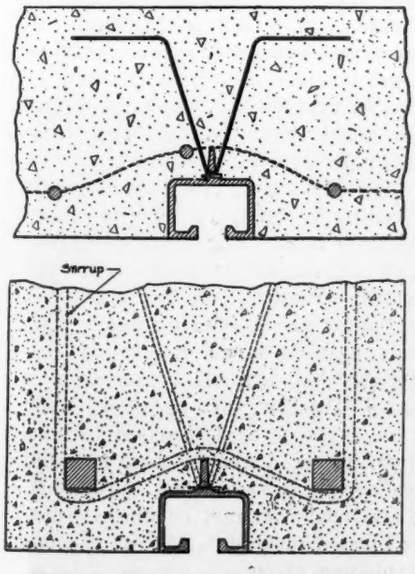


Fig. 13—These diagrams show the method of setting the box rail around the reinforcing in concrete slab and beam construction.

Fig. 12—One method of attaching a stringer to a standard I-beam. The hangers are then attached to the stringer.

Fig. 10 shows an installation of steel stringers in the maintenance and repair shops of the Interborough Rapid Transit Co., which operates the subway system in New York City. Railroad repair shops require, mostly, heavy-duty machine tools of greatly diversified character. Work is on a close schedule and usually on a 24-hr. basis. Here the bottom of the roof beams is 18 ft. above the floor. There is an exceptionally long span between the beams. Large diameter lineshafts 300 ft. long, which are paralleled by shorter shafts and lines of jack- and countershafts as shown in this illustration, are practically duplicated on the right of the telpher monorail track extending overhead down the center of this section of the shops. In this construction commercial 10-in. channels are used for the stringers and special steel footings for the hangers are fastened by special attachments. The channels were fabricated and riveted in sections at the steel works and attached to the frame of the building by clips. It is interesting to note that in this entire installation, Fig. 10, the groundwork with every piece of apparatus attached to it, was completely erected without the drilling of a single hole while it was being erected. Also, this installation could be re-erected in any other part of these shops, covering several acres, without refabrication. Flexibility of arrangement was paramount in this installation.

To the man responsible for the supervision of the installation of lineshafts perhaps one of the most important points to consider is the necessity of planning ahead on how this can be done on future additions to the plant, particularly if the plant is of concrete construction. It is futile to attempt to determine where the shaft is to be and to set two rows of box rails or a few inserts and expect to fasten the hangers to them. In all likelihood by the time the plant is built the plans will have changed so that the inserts will be far enough out of the necessary position so that they cannot be used. The only practical plan is to set box rails or inserts in the concrete on standard centers or at specified distances apart so that they may be used wherever it is desired to put the shaft in the first place or to remount it when necessary to move it. One Chicago plant for instance has inserts cast in the ceiling on 4-ft. centers each way. It is a very simple matter to erect or shift a lineshaft and the same material is used over again on the new job without any cutting or fitting.

Some of the methods of inserting box rails in the ceiling are shown in Figs. 11 and 13 and a more detailed description of their use given in the caption accompanying the illustrations. The concrete is poured around the box rail and it becomes a part of the reinforcement of the building. Box rails are also set in the walls to carry radiators, pipe and conduit lines, and support motors or machinery mounted on the walls.

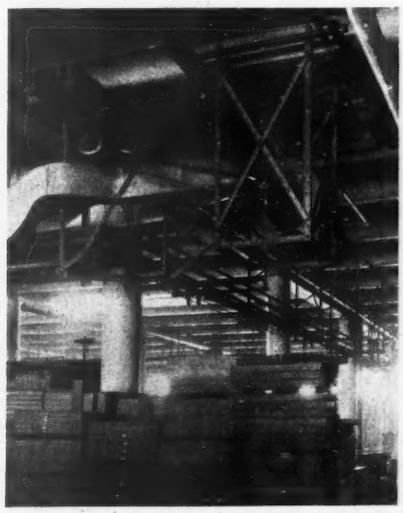
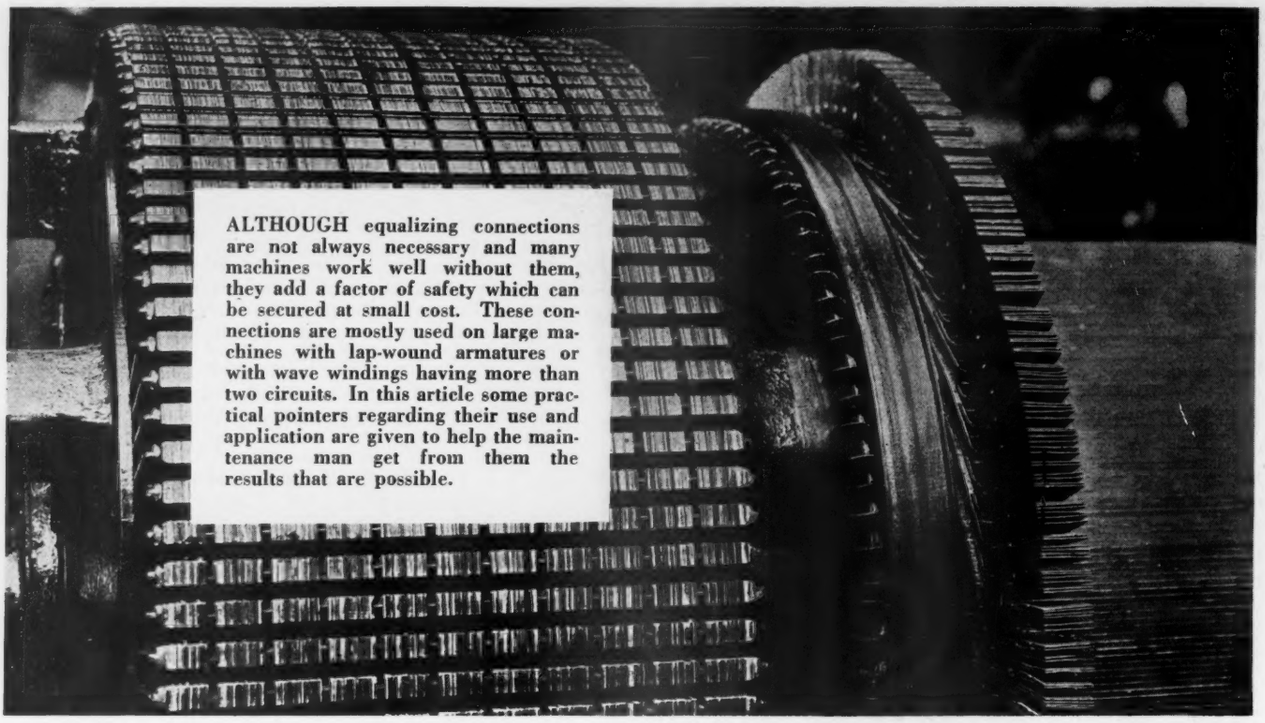


Fig. 14—Conveyors are also supported from the box rails and ceiling inserts.



ALTHOUGH equalizing connections are not always necessary and many machines work well without them, they add a factor of safety which can be secured at small cost. These connections are mostly used on large machines with lap-wound armatures or with wave windings having more than two circuits. In this article some practical pointers regarding their use and application are given to help the maintenance man get from them the results that are possible.

Fig. 1—This illustration shows a common type of cross connection consisting of one-turn open strap copper coils which are placed in two layers at rear of commutator.

Some of the reasons for using

Cross or Equalizer Connections on Lap Windings

together with practical rules governing the application of these connections, and a description of the different ways in which they can be arranged

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IN THIS article a brief explanation of the reasons for employing equalizer or cross connections on lap windings is given, with the necessary rules and methods for making use of such connections so that the shop man will know how to proceed to check up a rewinding job on which they are used.

In a motor or generator, the armature is concentric with the field poles; that is, the air gap is equal under each pole. Also the magnetic density is supposed to be the same under each pole. This may not always be the case, due to the inequality of materials used, and the armature may be out of alignment due to bearing wear or other causes.

This will allow one side of the armature to rotate in a stronger field and without cross connections, the above conditions will cause a current to flow between brushes of like polarity. In other words a circulating current will be set up in the windings and this current may increase to such magnitude as to damage the machine.

These circulating currents have the same effect as though two generators were mounted on a common shaft, and the potential of one raised above that of the other. Then, the machine having the higher voltage will act as a generator, while the other will act as a motor. This will cause dangerous sparking and burning of the brushes and also cause heating, thus decreasing the capacity.

There is also the possibility of the winding being damaged by these currents. However, when points of equal potential are connected together, the currents that flow through these cross connections in cases where the armature gets out of alignment are alternating in character, and are either leading or lagging in reference to their respective electromotive force. These cross connections direct the flow of the current so that they magnetize or demagnetize the field and automatically produce a balance.

This balancing of the magnetic circuits by cross or equalizer connections is also helpful in preventing any unbalanced magnetic side pull on the armature, should it get out of center due to bearing wear. This side pull on large, lap-wound machines that are off center only a small fraction of an inch, may amount to 5 or 6 tons and cause heating, rapid wear of bearings and excessive stresses on the shaft. This trouble cannot occur on cross-connected machines, for the reasons explained above.

Cross connections are not used on wave windings since the series of coils tends to automatically balance

or average any lack of uniformity between different poles.

Cross connections should connect together points on the armature that are of equal potential and like polarity; that is points 180 deg. apart on four-pole machines, 120 deg. apart on six poles, 90 deg. apart on eight poles, or 360 deg. divided by the number of pairs of poles for any number of poles. From the above it follows that there will be two equal potential points on a four-pole winding, three on a six-pole, four on an eight-pole, etc., or that there will be as many points as pairs of poles, and that the method used to connect these points must form a separate circuit or ring. There can be as many of these circuits as there are bars, but the most common method is to provide about 30 per cent equalization; that is, one-third as many rings as bars, the cross-section of the cross connection being 50 per cent of the armature conductor cross-section.

These cross connections are arranged on an armature in a number of different ways. Fig. 1 shows one common method, which consists of a two-layer, one-turn open strap copper coil winding, placed at the rear of the commutator.

As a general rule three or more straps are tapped together to form a winding unit and with this method 100 or 50 per cent equalization is generally used. The spacing is 1-and-2 or 1-and-3. With this type of connection each bar that is tapped has two connections to it; that is, a top and bottom equalizer lead. The distance in bars between top and bottom leads of any one cross connection is equal to the total number of bars divided by the pairs of poles. The disadvantage of this type of cross connections is that they are under the winding leads and hard to get at when it becomes necessary to make repairs.

Another type of cross connection placed at the rear of the commutator is shown in Fig. 2. This consists of S-shaped conductors nested together to form a two-layer winding, the equalizer bars having two taps made to it as shown in Fig. 2. The data for Fig. 2 are, 41 cross connections, 126 bars, 6 poles; the connector pitch is $126 \div 3 = 42$, or 1-and-43. The spacing is $126 \div 42 = 3$, or 1-and-4.

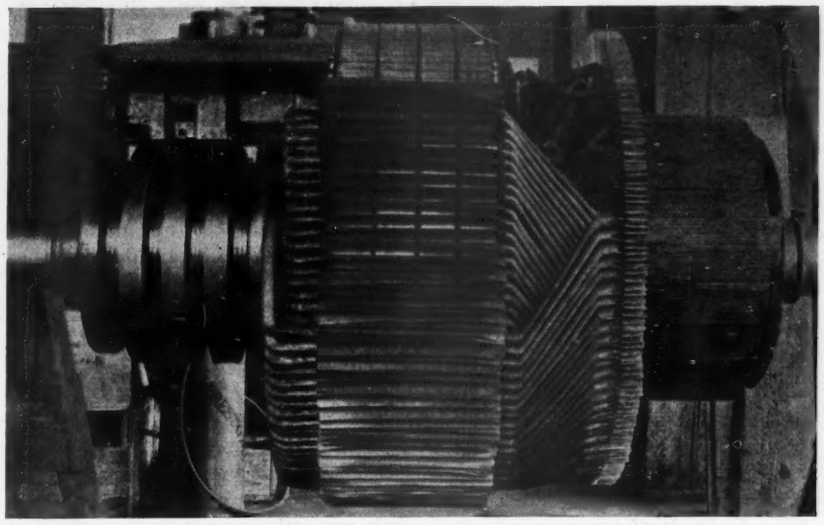


Fig 3—Here is another type of cross connection consisting of a number of rings of flexible cable tapped at proper points and with flexible leads brought out to the commutator bar necks.

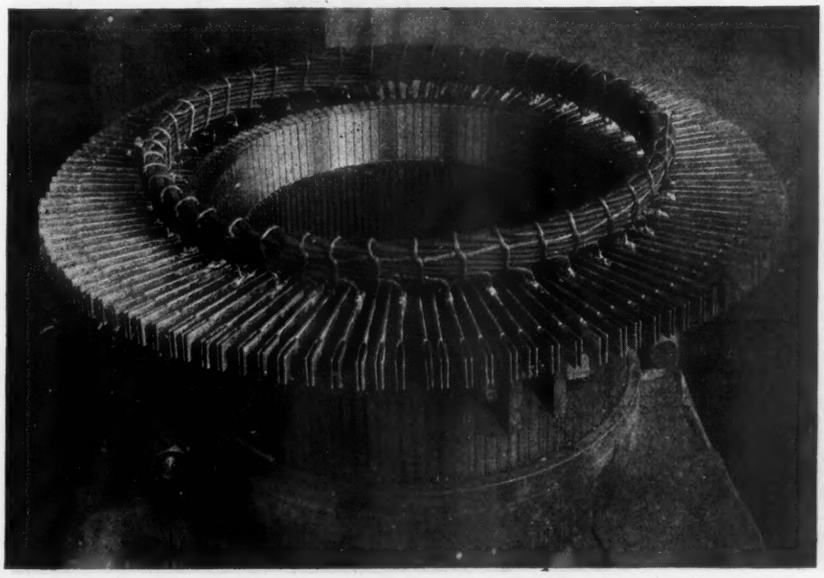


Fig. 2—This type of cross connection consists of S-shaped conductors nested together to form a two-layer winding with equalizer bars having two taps made to it.

Another type of cross connection used behind the commutator is shown in Fig. 3. This consists of a number of rings of flexible cable tapped at the proper points and flexible leads brought out to the commutator bar necks, as shown.

Another style of equalizer connection consists of a number of complete rings at the rear of the armature with taps taken off each ring at equidistant points. This type is shown in Fig. 4. The winding shown has seven rings, with seven taps to each ring, as the armature belongs to a 14-pole machine. There are $7 \times 7 = 49$ taps in all.

A type of equalizer connection used in small machines is shown in Fig. 5. This consists of a number of small rings with taps of thin strip copper. Each ring is insulated and assembled, one inside the other, and the whole bound together and connected to the winding when the latter is in place.

The latest type of cross connector is shown in Fig. 6, *A* and *B*. This consists of a number of S-shaped conductors, nested together to form a two-layer winding but placed at the rear of the winding where it is easily accessible. In Fig. 6*A* note the heavy supporting rings, and the method of tying the connectors to this ring. With this type a special loop is made at the rear end of the tap coil and this loop is drilled to receive one or two rivets. The connectors are fastened with rivets and then soldered, making a good sub-

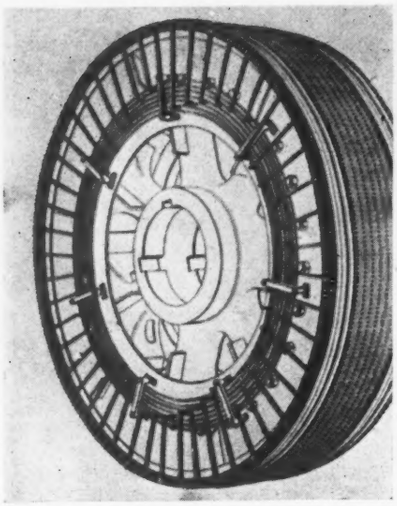


Fig. 4—In this arrangement of equalizer connections there are a number of complete rings at the back of the armature with taps taken off each ring at points spaced equal distances apart.

stantial construction. In Fig. 7 are shown equalizer connectors that form a two-layer winding at the rear, the connectors being involute-shaped.

In what follows some winding rules are given for applying equalizer or cross connectors.

Consider the ring type first, and refer to Figs. 3, 4 and 5. As stated before, points on the commutator or winding that are (No. bars ÷ pairs of poles) apart should be connected together. It follows then that the least number or rings will be equal to one ring for each pair of poles; that is, there will be two rings for a four-pole machine, three for a six-pole, four for an eight-pole, etc., and the least number of taps per ring will also be equal to one-half the total number of poles. The maximum number of rings would be equal to the number of bars or single coils divided by the number of poles.

The number of rings times the number of taps per ring $(R \times T)$ determines the spacing. The number of bars $\div (R \times T)$ must be a whole number for the number of rings selected to wind.

For example, consider a 14-pole machine with 224 bars, 112 slots, 2 coils per cell. Then the pairs of poles equal 7, the least number of rings also equals 7, and the taps per ring equal 7. The total number of taps $(R \times T)$ equals 7×7, or 49, and the spacing is $224 \div 49 = 4\ 4/7$ which gives an unequal spacing that will not wind. Next, find the least common multiple of 224 using the number of taps per ring as the first factor, or $224 \div 7 = 32$. By dividing this answer by the largest possible divisor, we find the smallest number of rings that will wind, or $32 \div 8 = 4$. Trying eight rings,

Fig. 7—This photograph shows an equalizer connection that forms a two-layer winding at the rear, the connectors being involute-shaped.

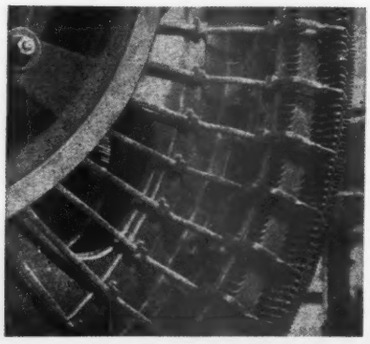
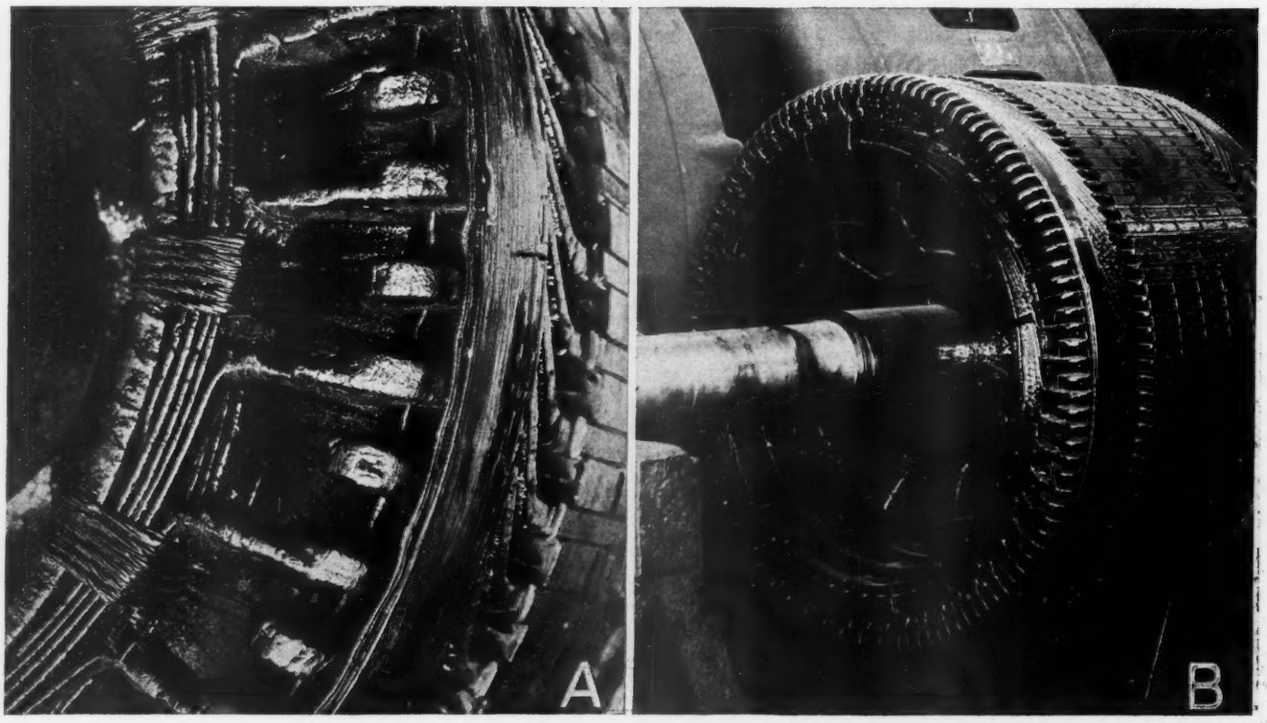


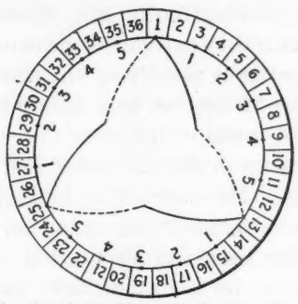
Fig. 5—In small machines equalizer connections are used that consist of a number of small rings with taps of thin strip copper.

Each ring is insulated and assembled one inside the other and the whole group bound together and connected to the winding when the latter is in place.

Fig. 6—This is a modern type of cross connection.

It consists of a number of S-shaped conductors nested together to form a two-layer winding and placed at the rear of the winding. In *A* note the heavy supporting rings and the method of tying the connectors to the rings.





For this 6-pole machine with 36 commutator bars, Connector pitch = 36÷3=12 or 1 and 13
Per cent of cross connection with different spacings
1 and 2 = 100 % cross connection
1 " 3 = 50 % " "
1 " 4 = 33⅓ % " "
1 " 5 = 25 % " "
1 " 7 = 16⅔ % " "

Fig. 8—This diagram shows a way of determining the number of connectors that can be used with any winding by proper spacing.
Three equalizers are shown for a two-layer type of cross connection, these equalizers being connected to bars *1*, *13* and *25*.

(R×T) equals $8 \times 7 = 56$, and $224 \div 56 = 4$, or the spacing will be 1-and-5. The pitch between taps on each ring will be $224 \div 7 = 32$.

We can now lay out the ring data as follows: Ring No. 1 will connect with bars *1, 33, 65, 97, 129, 161, 193*, or starting with bar *1*, we add the top pitch until a number of points equal to the number of pairs of poles per ring are tabulated. To check each ring add one more pole pair pitch, which should give the bar number that the series of ring taps started on, or 193 plus 32 equals 225 or bar *1*. The spacing is 4, or 1-and-5; therefore, the first tap to ring *2* will start at bar *1* plus 4 equals bar *5*. The other taps will be on bars *5, 37, 69, 101, 133, 165, 193*, and ring *3* will start at bar *5* plus 4 or *9* and connect to bars *41, 73, 105, 137, 169, 197*. Ring *4* will connect to bars *13, 45, 77, 109, 141, 173, 201* and ring *5* to bars *17, 49, 81, 113, 145, 177, 205*, etc.

With the two-layer type of cross connector, the spacing also determines the number of connectors that can be used with any given winding.

For example, consider Fig. 8 which shows a 36-bar commutator for a six-pole machine. The equalizer pitch will be $36 \div 3 = 12$, or 1-and-13. Three equalizers are shown connecting bars *1, 13, 25*, which is practically a three-tap ring, except that each circuit or ring consists of three parts; that is three "S" or involute-shaped end connectors, arranged in two layers. The dotted lines indicate the bottom part of the connector and the full lines the top part. Now 100 per cent equalization would mean 36 connectors and 50 per cent cross connection would require $0.5 \times 36 = 18$ connectors. The spacing would be $36 \div 18 = 2$, or 1-and-3, as indicated by the dots and small figures in Fig. 8. The figure 1 at the front of bars *3, 15, 27*, indicates that the second series of connectors touch these bars. There is also a spacing of 1-and-4, 1-and-5, and 1-and-7 giving 33 1/3, 25 and 16 2/3 per cent cross connection.

Precautions to Take Against Freezing of Fire Extinguishing Appliances

UNLESS extreme vigilance is exercised the very best installation of fire appliances may suffer temporary disablement from frost. Automatic sprinkler systems, hydrants and all appliances using water for fire extinguishment naturally require special care and attention in winter. The following precautions, which are given by the National Fire Protection Association, Boston, Mass., should be taken, and thorough inspections made, with nothing taken for granted:

See that all portions of buildings are properly heated to at least 40 deg. F. at all times to prevent freezing in any of the sprinkler pipes, particular attention being given to exposed places such as hallways, entries, stair towers, elevator shafts, shipping rooms, attics, roof monitors and skylights, and spaces between ground and first floor and under sidewalks. Examine tanks and all pipes, fittings and valves, whether for steam heating, general water service, or fire protection. Besides seeing that tank heaters are in proper order it is important to make certain that they are of adequate capacity for the tanks they serve. Examine carefully and provide suitable boxing around any pipe lines which may be in exposed locations such as either between ground and first floor, between buildings, or near windows, and so on. Make frequent tests during the winter in order to make sure the piping is free from frost.

Where water barrels, pails, or hand pump extinguishers are located in rooms subject to freezing temperatures, use calcium chloride to lower the freezing point of their contents. The accompanying table shows approximately the temperatures at which water will freeze when calcium chloride (commercial, 75 per cent) is added in the proportions shown to depress the freezing point:

Quantities Used to Make 2½ Gal. Anti-Freezing Solution

Freezing Temp. Deg. F.	Water Gal.	Calcium Chloride Lb.	Oz.	Specific Gravity	Deg. Baume
+10	2¼	5	..	1.139	17.7
zero	2⅛	6	4	1.175	21.6
—10	2	7	6	1.205	24.7
—20	2	8	6	1.228	26.9
—30	2	9	2	1.246	28.6
—40	2	10	..	1.263	30.2

The strength of the solution obtained may be tested by using a hydrometer to determine the specific gravity. About a tablespoonful of lime added to each pail will prevent acidity and consequent corrosion. The inside of all containers to be used for calcium chloride solution should be coated with asphaltum paint.

Calcium chloride is recommended in place of common salt because the latter will always rust metals. In an emergency, common salt (not rock salt) may be used when the solution is kept in wooden casks and where temperatures lower than zero F. will not be encountered. Two and three-quarters pounds of salt to each gallon of water should be used, producing a solution having a specific gravity of 1.205.

Anti-freeze extinguishers normally employing solutions which will withstand temperatures as low as 40 deg. below zero require no special attention in cold weather. When extinguishers are not of the anti-freeze type (i.e. are either of the soda acid or foam type) the following precautions should be observed. See that no extinguishers of these types are exposed to temperatures lower than 40 deg. F. Diluted sulphuric acid may freeze at a higher temperature than water; at from 36 to 38 deg. F. there is likely to be material precipitation in the soda solution. The freezing point of the soda solution is practically the same as that of pure water.

Absolutely prohibit the addition of "non-freezing" compounds of any character to the contents of these extinguishers. Extinguishers have frequently been rendered inoperative by this means, and fatalities are on record, due to bursting of extinguishers as a result of corrosion induced by such treatment. The addition of salt or calcium chloride to the soda solution causes chemical changes which defeat the essential principle of operation of these appliances.

To thaw water pipes that have become frozen, wrap the frozen section with cotton cloth and pour hot water upon it until the ice in the pipe gives way. Rags on the floor at the base or under the pipe will absorb the waste water. Good results have also been secured by use of electricity where proper apparatus was available. A burning match, torch or open flame of any description should never be employed to thaw pipes. To wrap the pipes with oil-soaked rags and set them on fire is worse than folly; it is incendiarism.

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

D. H. BRAYMER, *Consulting Editor*
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Best Wishes for a Happy New Year to All of Our Friends

DURING the past year 558 contributions from 243 readers have been published in the pages of INDUSTRIAL ENGINEER. In addition, many other readers have made suggestions and comments which have been very helpful.

The Editors of INDUSTRIAL ENGINEER take this opportunity of thanking those who have thus co-operated with them in these and other ways that are highly appreciated, and extend to all of our readers and friends, everywhere, the most sincere good wishes for a Happy and Prosperous New Year.

Why Not Take the Shackles Off the Squirrel-Cage Motor?

ALTHOUGH the squirrel-cage induction motor is now widely employed, there are certain hindrances in the way of its fullest use. Principal among these are the limitations imposed by many power companies in regard to the size that can be connected to their lines. While there were good reasons ten or more years ago for setting up rules governing the maximum size of squirrel-cage motors permitted on a power distribution circuit, with slip-ring motors required above that rating, no such conditions exist today and limitations of a bygone day are now out of step with the progress of the electrical art, particularly in the improvements in motor starting and control devices.

Realizing that that there would be a constant increase in the size of squirrel-cage motors used, the electrical control manufacturers long ago set out to devise ways and means to apply this type in its larger ratings so as to overcome the objections offered largely by the power companies. Remarkable results have been accomplished through the automatic operation of squirrel-cage motor starters, but still the power companies show little interest in changing the old rules dealing with current values when starting such motors.

There is no question that this indifferent attitude is holding back progress in the application of electric power and it will continue to do so until antiquated starting rulings are changed. Today it is a well-recognized engineering fact that line disturbance when starting induction motors is caused not so much by the amount of current drawn from the line as by the suddenness of drawing this current. Any rules that specify the amount of current that can be drawn during the starting period without specifying the time element in connection therewith are not only unfair to the squirrel-cage motor but plainly indicate that their sponsors are not keeping up to date on motor and electric control engineering. Moreover, this indifference on the part of power companies is penalizing an electrical application that has been and always will be the greatest factor in building up a station load; namely, motors in the larger sizes.

The squirrel-cage induction motor is, when properly loaded, an ideal type for general purpose application, because of its simplicity and reliability, and if power company rules stand in the way of its possible use some method should be adopted to remove the rule, rather than to remove the motor or bar its installation. Industrial plant operators and managers can do much by collecting graphic voltage and current records of squirrel-cage motor performance and discussing these with the managers and engineers of local power companies, and by bringing the matter up for discussion in the meetings of local engineering societies. If such action fails of success, this is a suitable subject to bring before state regulating commissions having jurisdiction over the service furnished to the public by electric light and power utilities. Certain it is that a ruling that forces the use of slip-ring motors when squirrel-cage motors could be used at a lower cost and provide a suitable application from an engineering and operating standpoint are unjust and arbitrary and need relief. Concerted action on the part of the user, based on sound engineering, will bring about relief.

High Voltage and Dirty Insulation Are a Dangerous Combination

OFTENTIMES it is the overlooking of little things in plant maintenance that causes long delays in production. For example, a flashover recently occurred on the slip rings of a 2,000-hp., 2,200-volt wound-rotor, induction motor forming part of a variable-speed drive in a steel mill. The slip rings were apparently in good condition, but on again applying power to the motor a second flashover occurred.

The secondary voltage across the slip rings at the instant of starting is around 1,100 volts. Knowing this, the electrical superintendent thought the insulation around the rings might be dirty. So the rings were blown out with compressed air and another unsuccessful attempt made at starting. Then various other expedients were tried, such as putting in asbestos barriers between the rings, all of which failed.

Meanwhile the entire mill was down for nearly three hours, causing a serious interruption to production. As a last expedient the troublesome motor was switched to the spare bus in the power house. A separate generator was used to bring up the voltage gradually on this bus and the motor connected to it. In this manner

the motor was brought up to speed without trouble.

The following Sunday, the slip ring insulation was thoroughly scraped and cleaned off, after which it was painted with clear insulating varnish. The trouble did not recur, thereby proving that dirty, carbon-covered, slip ring insulation was the cause of the trouble.

A little cleaning and painting of the insulation of all high-voltage parts will go a long way towards cutting down many of those hard-to-find troubles that run up into long delays.

Low Price Will Not Compensate for High Operating Cost

THE question, "What Comes After the Purchase Price?" which an automobile manufacturer recently used in advertising his car, applies just as well to the purchase of any piece of equipment or supplies used in the operating department of an industrial plant. An automobile purchaser looks into the reputation of the car he buys, because he desires to be sure that it will take him where he wants to go, bring him back, have low operating cost, and stay out of the repair shop. The industrial executive also expects reliability and low operating and maintenance cost of the equipment he buys, whether the service demands operation for 10 hr. or 24 hr. a day.

Operating men who look only at first cost and disregard what may come after usually find that, if they keep accurate records, the after-cost of maintenance over a reasonable period added to the first cost, often exceeds that of the highest-priced piece of similar equipment on the market.

The cost of production delays, with their interference to output and the expense of idle men is an additional expense which should be, but seldom is, charged directly as a part of the cost of the machine.

Examine the Fuse Clips Before You Blame the Fuse

THE necessity of having as perfect a contact as possible between fuses and their supporting clips is so obvious as to admit of no argument. Nevertheless in many cases little attention is paid to this point, with the result that a good deal of trouble is experienced, for which the fuse is unjustly blamed.

As a case in point, when a new installation of 440-volt panel and control boards was put in service some time ago serious trouble from blowing of fuses developed at once. In addition, some of the fuse blocks and cables became so hot that several slate panels were cracked. Overloads were first blamed for the trouble, but careful checking showed that the loads carried on the various boards were not excessive. What was considered to be a thoroughgoing investigation of the whole installation failed to show the cause of the trouble. In the meantime fuses kept on blowing.

Eventually it occurred to someone to check up the fuse clips. Then it was found that the area of contact between the fuses and clips was not sufficient to carry the load current without heating, which resulted in the fuses being heated far above the normal working temperature. When sufficient contact area was provided there was no further trouble.

Blowing of a fuse ordinarily creates an emergency condition which must be met as soon as possible by putting in a new fuse. Under the circumstances it is easy to overlook the fuse clips. If they do not make a firm, low-resistance contact, trouble is almost certain to develop sooner or later. It is inconsistent, to say the least, to solder or firmly bolt all other connections in an electrical circuit and then leave the contacts at the fuses to chance.

A few minutes spent in checking up the condition of fuse clips, cleaning and tightening them when necessary, will save much unnecessary trouble and expense.

Take an Inventory of Equipment That You Need But Do Not Have

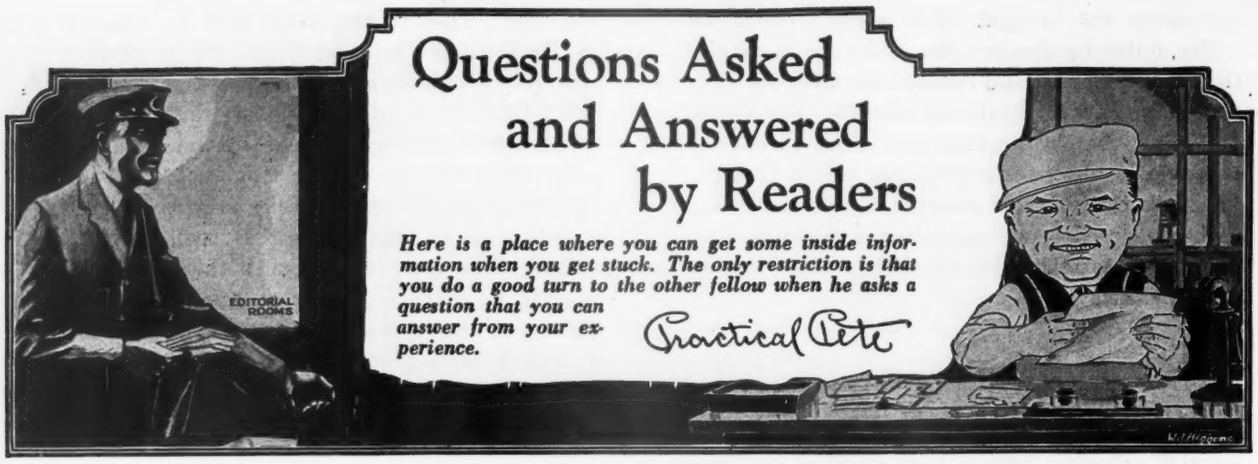
AT THIS time of the year it is the practice in many plants to take an inventory of all equipment and material on hand. For business reasons this is necessary and serves a useful purpose. However, an inventory of the equipment that you need but do not have may show how maintenance and repair costs could be materially reduced.

Probably on more than one occasion during the past year precious time has been lost in an emergency because some tool or piece of equipment that could have been used to good advantage was not available.

Likewise, memory may recall one or more instances where breakdowns of important production equipment could have been foreseen and prevented if the proper testing equipment had been available and consistently used. Again, a few hours spent in watching your men at work may serve to show where up-to-date coil making and baking equipment could replace hand work and clumsy makeshifts at a saving in time and labor; or where an electric drill or hammer could save hours of hard work; or where a few indicating and graphic instruments would take the guesswork out of load surveys and the selection of motors and other equipment; and so on through the many and varied activities of operating and maintenance work.

It is a mistake to think that there is any real economy in doing by hand work that could be done by machine, or in using inefficient makeshifts, or in simply getting along without equipment that is needed. Under present conditions, in a modern, growing plant, good testing and repair equipment will, when properly used, pay for itself within a reasonable period.

If there is any doubt on this point, put down opposite the price of each piece of equipment that you need but do not have, what the lack of it has cost during the past two or three years, in hand labor and production delays. The result may surprise you.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Selecting Belts for Oily Work.—We have had considerable trouble with the drives in the screw machine department of our plant due to the belts getting soaked with oil. We have been using leather belts. I would like to know whether there is any treatment I can give these belts to make them oilproof or if there is any belt which is not affected by the oil. Also, how do other men with a similar problem remove the oil from the used belts and put them in condition for service again?
Chicago, Ill. G. F. H.

* * * *

Cleaning Wire-Mesh Carbon Brushes—What is the best way of cleaning wire-mesh, carbon brushes that are heavily coated with carbon dust and dirt? Scraping with a knife is slow and not entirely satisfactory. Is there some solution that could be used to clean them? These brushes are used on an old plating generator that is subjected to frequent overloads and the commutator is slightly grooved; so there is considerable sparking. The commutator has been turned down about as much as it can be and as the generator will be replaced before long we do not want to put on a new commutator. However, I must keep the generator in as good condition as possible until it is replaced.
Milwaukee, Wis. A. J. K.

* * * *

Laying Out Electric Repair Shop for Steel Plant.—We are planning to build a new shop for doing our electric repair work. This shop will handle the necessary repairs on motors and control in a steel plant having about 1,000 modern motors both a. c. and d. c. During normal operation 14 men are required in the shop. Naturally the shop will have a coil-winding section; so provision must be made for winding equipment and supplies. In addition there will be a lathe, insulation cutting shear, baking oven, armature press, test rack and other shop equipment. I would like to obtain the views of readers as to what would be the most practical layout of a repair shop for this class of work. Possibly they have found certain arrangements of repair shop equipment that have produced money-saving results.
Indiana Harbor, Ind. A. R. D.

* * * *

Reducing Motor Hum on Large Ventilating Fans.—In the operation of induction motors the lower the speed the greater the motor hum. In some cases however, it is necessary to use low-speed induction motors on ventilating fans and in this case excessive motor hum is objectionable since it is transmitted through the fan and to the duct system. If readers have devised ways and means to reduce the transmission of this hum by suitable mountings for motors when direct connected to the fan by using some fibrous or other material that reduces the transmission of noise, I would like to get details of such mountings. Possibly the noise-reducing device may take some form of coupling between the motor and fan. Please indicate also how magnetic density and variations in slip to get low-speed operation effect motor hum.
Omaha, Neb. H. A. P.

* * * *

Method of Changing Two-Phase, Four-Wire System to Two-Phase Three-Wire System.—Our power supply is from a two-phase, four-wire system. For various reasons I wish to change the distribution to a two-phase, three-wire system. Will some reader tell me how to determine which wires of the four-wire system should be connected together to form the common or neutral wire? Is it possible to tie together the wrong pair of wires to form the neutral? How should the four-wire, three-phase motors be connected to the three-wire system? Are there any precautions to take in connecting motors to the three-wire system? Will this change affect anything else in the plant?
New York, N. Y. J. M.

* * * *

Armature Bands Overheat.—Five bands are used on a 220-volt, d. c. armature with which we are having trouble. The armature coils slope very sharply and to prevent the outside bands from slipping off the ends of the armature, the winder soldered copper strips across the bands so as to tie them together. Six ⅝-in. strips were placed parallel to the coils and spaced at equal distances around the armature. The bands as well as the copper strips are well insulated from the armature winding, but the bands and particularly the copper strips become very hot, presumably from some induced current. I would like to know what causes this heating and how it may be prevented. If it is induced current that causes the heating please explain what causes this current. Is there any way in which I can tie these bands together that will not cause the heating referred to?
Oelwein, Ia. L. T. M.

* * * *

Starting Large Induction Motors.—The local power company does not permit the connection of squirrel-cage motors larger than 25-hp. capacity to its line. Above this size a wound-rotor induction motor is required. Such a motor and its control are of necessity more expensive. It is my understanding that some forms of resistance starters for squirrel-cage motors will cause the initial current peak to build up gradually and consequently create no voltage disturbance on the power company's lines. If any readers have used such starters on motors larger than 25 hp., so as to meet the requirements of power companies and have successfully shown them that motors larger than 25 hp. can be started without line disturbance, I would greatly appreciate learning the details of the application. I would also like to learn the motor size, voltage, speed of motor, and type and maker of starter in each case.
Cedar Rapids, Ia. H. P.

Answers Received To Questions Asked

Proper Babbitt for Armature Bearings—I would like to learn the experience of other readers as to what kind of bearing metal they find to be most suitable for armature bearings. Is a lead-base babbitt best suited for armature bearings of motors, which are geared direct to the driven machine? With what type of bearing metal do you get the best results on armatures that are direct-connected or belted to the driven machines? There are on the market a great many varieties of bearing metal, including babbitt and various bronze alloys, and I shall appreciate any information that you can give me regarding the selection and application of such metal for use in armature bearings.
Pittsburgh, Pa. H. D.

In reply to the question by H. D., I suggest the use of Westinghouse Alloy No. 14 for his motor bearings. With a proper amount of oil, the motors may be used for any service without fear of bearing trouble.

I would like to hear from H. D., if he does not have good results with this type of alloy.
Oelwein, Ia. L. T. MILLER.

* * * *

Answering the inquiry by H. D., I might say that at one time I was sales manager for a foundry and had a share in the creation of a volume of argument in favor of the use of high-priced, secret bearing alloys. From this experience I can appreciate how confusion may arise when selecting the proper kind of bearings.

Strictly speaking there are only three kinds of bearing metals: (1) soft babbitt; (2) hard babbitt; (3) bronze. Babbitt is used where the bearing is likely to be rebabbitted for longer life and bronze is used where a one-piece bushing is more convenient for maintenance purposes. Unless a bronze bearing is kept oiled it will freeze and cut the shaft, while babbitt will run dry for a time without harm to either shaft or bearing.

In regard to alloys, the best type of bronze to use as listed in most handbooks is given as 88 per cent copper, 10 per cent tin and 2 per cent lead. This is an old stand-by which has not been improved to any great extent. In the case of H. D., he could use babbitt with good results.
Elgin, Ill. SVEND E. SALOMONSON.

Answering H. D.'s question in a recent issue as to what bearing metals are best to use in motors, I recommend a bronze type bearing that has given excellent satisfaction on motors rated from 10 to 50 hp. and operating at speeds between 700 and 1,000 r. p. m.

These bronze bearings are composed of 80 per cent copper, 12 per cent lead, and 8 per cent tin, and are used for motors directly coupled to a reversible drive-shaft by a solid coupling. In boring out these bearings about 0.0025 in. to 0.004 in. clearance depending on the diameter of the shaft, is found to be the most satisfactory. These bearings are lubricated by means of oil rings. A medium grade of machine oil is used.

Long life is one of the chief characteristics of bearings made with this mixture and they have proved their adaptability for elevator use over a number of years.

Asst. Chief Engineer, J. M. WALSH.
Guerney Elevator Co.,
New York, N. Y.

* * * *

Answering the question by H. D. in the November issue of INDUSTRIAL ENGINEER, I would like to mention the fact that we have adopted the practice of using Parsons White Bronze metal exclusively for all of our motor bearings. There is no question in my mind, however, that almost any good grade of babbitt with a fairly close grain is satisfactory for motor bearings where the drive is direct, providing there is no side thrust due to gears or belts.

In order to prevent wear when motors are belted or geared to the driven machine, there must be an unbroken oil film between the journal and the sleeve at the point where the side thrust occurs. This oil film may become broken down by oil-ways cut at the point of maximum pressure or where a sleeve is too loose, and not parallel with the journal. Other causes might be rough journals, bearings, or both, and in some cases the grade of oil might be too light to stand the pressure. Most of our drives use either gears or belts, which cause considerable side thrust. We use the white bronze because it is harder than ordinary babbitt and has the very desirable feature of polishing the journal, which in turn causes minimum wear on the sleeve.

Our first application of white bronze metal was made about three years ago on a 100-hp. motor that is used on a coal hoist and operates almost 24 hr. a day. It was thought up to this time that hard bronze was the only kind of material which would stand the weight and service. However, we were putting in new bearings about every three weeks and the journals were so rough they had to be redressed or built up each time, a condition which we felt should be remedied. The first set of white bronze bearings operated eight months and the journals looked like polished tool steel. These bearings have been changed two or three times, but the journals still maintain their polish and so far have required no work on them. We were so well pleased with these results that we commenced using this material in place of babbitt on other motors, with entirely satisfactory results.

We have applications where a cheaper and softer material would serve, however, our motor bearing troubles have declined to such an extent since using this material that it is not worth while stocking another kind. In the end the cost is really no more as the bearings we now use wear longer and have eliminated considerable work on the journals.

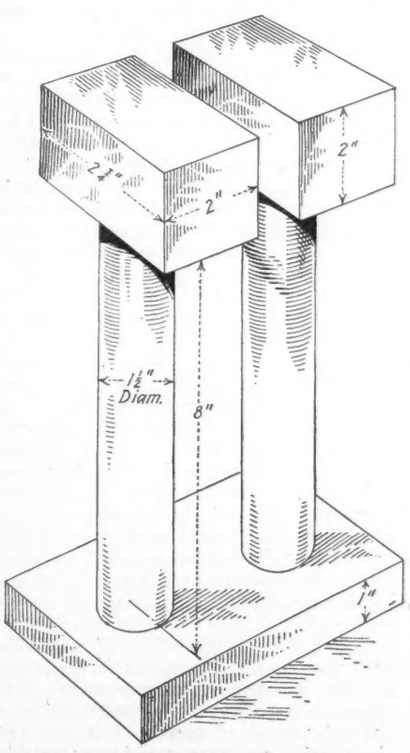
If H. D. is having trouble with motor bearings, I suggest that he first check up on the mechanical details, as mentioned above, to be sure that dirt and grit are not allowed to accumulate in the oil wells; then if this does not eliminate the trouble, try the white bronze bearing metal.

CHESTER A. WILLIAMS.
Providence Gas Co.,
Providence, R. I.

* * * *

How to Make a Magnet Recharger—I wish to build a coil for recharging or remagnetizing magneto magnets. This coil is to operate on 220 volts direct-current. I shall be glad to get any information regarding dimensions of core, turns and size of wire, and so on, that other readers can give me.
Somerset, Pa. G. G. F.

In answer to G. G. F., the accompanying sketch shows an electromagnet for recharging magneto magnets, which has been found very satisfactory and easy to construct. The base is of cast iron 1 in. thick, with two wrought-iron cores 8 in. long and 1½ in. in diameter mounted on it. Each of these cores is wound with 14,000 turns of No. 27 B. & S. gage d.c.c. magnet wire and both coils are connected in series for use on 220-volt d.c. circuits, or in parallel for 110-volt circuits. Where this arrangement is not required, or to make the magnet somewhat cheaper to build, half the number of turns given above and wire of twice the cross-section will make it suitable for service on 110-volt d.c. circuits only.



Details of electromagnet for recharging magnets.

The two cores are surmounted by wrought-iron blocks, 2 in. high, 2 in. wide, and 2¾ in. long. The complete electromagnet is usually mounted at some convenient point on the work bench so that just the two iron blocks project above the bench. The magneto magnets are recharged by moving them back and forth a few times across the face of these blocks.

Cleveland, Ohio. P. JUSTUS.

* * * *

Answering G. G. F.'s question, this magnet recharger may be made as follows: The coils should have 220 turns each of No. 18 or 19 d. c.c. magnet wire wound on solid iron spools. These spools should be about 2 in. in diameter, 5 or 6 in. long and bolted to an iron plate at least ½ in. thick. The coils should be wound in opposite directions and the inner ends connected together. The outer leads should be connected to the power supply through a suitable switching device and fuses.

HARRY J. ACHEE.
Chief City Electrician,
Woodward, Okla.

* * * *

How to Determine Horsepower of a Shaft or Clutch.—Manufacturers of couplings, clutches and other transmission equipment rate their equipment in horsepower per 100 r.p.m. Thus a device that will transmit 10 hp. at 100 r.p.m. would transmit 25 hp. at 250 r.p.m. I understand clearly that the horsepower per r.p.m. is the same in both cases. However, it seems to me that the shock to both clutch and lineshaft caused by operating a clutch at 250 r.p.m. would be so much greater than at 100 r.p.m. that a heavier clutch would be required.

I should like to get the opinions of readers on this point. In particular I should like to know what allowances, if any, they make for clutches and other power transmission equipment operating at speeds higher than 100 r.p.m.
Grand Rapids, Mich. E. E. H.

In discussing the question asked by E. E. H. it is well to begin by explaining the purpose of a clutch and other power transmission equipment. In a machinery installation it is often found desirable to have a coupling between certain of the parts, so made that it can be readily disconnected, to render two parts absolutely independent of each other, insofar as motion is concerned.

There are several ways of accomplishing this; one is to use a regular split shaft coupling, which is removed entirely when occasion demands; another is to use a flange coupling with an independent plate between the two halves. When it is desired to disconnect the coupling the bolts are taken out and the plate is removed. This plate is commonly termed a distance plate. A third method is to use what in days gone by was generally termed a dental clutch, so-called because each half had teeth, usually three, projecting from the face which clutched each other when the two halves of the coup-

ling were brought together. Of late years these projecting teeth have been called jaws, and this device is now quite generally referred to as a jaw clutch.

The first two of these devices require a complete stoppage of motion in order to break or make the connection, while the third requires a practical shutdown; so that unless the breaking or making of connections can always be made during regular shutdown periods, their use results not only in very considerable inconvenience, but often in considerable expense because of loss of operating time.

To overcome the necessity of shutting down completely or slowing down, as required by these expedients, the friction clutch was devised, and it has been worked out so successfully that it is used satisfactorily on shafts running not only at normal speeds but also at extremely high rates of speed and can be engaged freely and disengaged without interrupting the motion of the shaft, or shafts, upon which it is mounted. However, the success or failure of the friction clutch is predicated wholly upon the selection of a mechanism which has ample power capacity to meet all of the load conditions which are involved in the installation where it will be used.

The automobile offers a very good example of this particular point, and all that it involves, for it makes use of a friction clutch.

Notwithstanding the fact that the power plant of the car may be fully capable of driving it 60 to 70 miles per hour, the engine will invariably stall if, when the car is standing still, the clutch is engaged in high gear. Here the clutch holds and the engine stops, but that is only because the clutch is always made with power capacity which is in excess of the maximum which the engine can deliver. If the engine were stronger than the clutch, the clutch would slip and the engine would keep on going. In fact, this sometimes does occur, but the driver soon recognizes that his clutch is slipping and takes immediate steps to correct it. Of course, if both the engine and clutch capacities were great enough to overcome the starting resistance offered by the car when "in high" starting in this way could be accomplished, which is the condition usually met in the use of clutches in a factory.

There is usually ample capacity in the factory power supply to handle any pick-up which may be involved in driving any particular machine; therefore the problem comes back to the selection of a clutch which has sufficient power reserve to successfully cover the excessive starting strains which are involved.

Sometimes, as in the case of oil and gas engines and electric motors, the problem in a factory is similar to that in the automobile; that is, the power unit has ample capacity to drive the plant after the machinery is in motion, but it cannot start up under the load and consequently the power unit must be started and be run up to speed before the load can be thrown upon it.

In a case like this the friction clutch must not only be considered from the standpoint of its ability to handle the excessive strains which the picking up a dead load involve, but also on the basis of its ability without frequent readjustments, to stand the slipping which must take place during the picking-up period and before final engagement occurs. Under conditions like this a certain amount of easing in and prolongation of the period of engagement, with the accompanying increase in slippage, must be allowed in order to prevent backing the starting strains into the power unit in such a way as to stall it.

Along with these points, the frequency with which the clutch is operated should be considered for, of course, the more often the operation takes place the greater will be the wear on the friction surfaces. It may seem advisable to use a larger mechanism than might otherwise seem ample in order to increase the area of the friction surfaces. Because the wear is directly dependent upon the pressure imposed upon each unit of friction area, increasing the total area will reduce the pressure on each unit and consequently reduce the wear on the friction surface.

This problem of pressure should also be considered in connection with the bearing surface, which in the case of a clutch pulley runs loose on the shaft, for if the loose hub or sleeve does not possess sufficient area the pressure resulting from the pull of the belt will result in lubrication difficulties and then wear, which will soon cause trouble. This wear is particularly troublesome when the clutch is on the driving shaft, for when it is disengaged the sleeve is standing still on the running shaft, and unless ample bearing area is provided the shaft will wear a pocket in the sleeve along the line where the pressure comes. The sleeve does not always come to rest in the same position, so that, in the course of time there will be worn a series of pockets, which even though very small will be sufficiently large to cause operating troubles. On this account it is well to consider some form of renewable sleeve lining for an installation of this particular type. Babbitt makes a very easily replaceable sleeve bearing surface.

In the cases of the split, flanged or jaw clutches, the matter of selection does not involve any particular problem for these are generally designed to have ample strength to handle all the power which should be carried by the shaft for which they are regularly bored. In the selection of a friction clutch, the situation is different; consideration must be given to the fact that one part of the clutch, and the load back of it, are standing still and must not only be picked up from rest, but also brought up to speed by the other part which is running at a fair rate of speed.

A friction clutch while of necessity allowing a small amount of slippage in the process of engagement, also engages definitely and positively in a limited period of time. If it did not, the friction surfaces would very quickly wear down, so that in order to keep the clutch in shape to function it would be necessary to be constantly adjusting it to maintain the friction surfaces in proper relation to one another.

Because of this fact, the starting loads must be considered largely from the viewpoint that during the period of clutching they produce strains similar to those resulting from instantly applied shock loads. It is for this reason that good judgment dictates overload capacities of two to four times the normal load requirements in clutches which are to be used to deliver power to machines with flywheels, such as compressors and punch presses, and, in fact, any machine which has a heavy mass to start up and bring up to speed.

Clutches running at high speeds or driving high-speed machinery should also be considered in this same way, because starting the load up from rest and bringing it up to a high speed inside of only a few seconds involves starting strains often many times the magnitude of the strains involved in keeping the machinery running properly after it has been put in motion.

It is often found that a clutch is to be used in connection with a pulley which must be of a certain face to match up with the pulley on the machine to be driven, and of a certain diameter to give the machine the proper speed. At the same time it is estimated that the amount of power required to operate the machine is considerably less than the belt running over this pulley can readily transmit. It is always well, however, to select a clutch which is equal in capacity to that which the drive figures, for in 99 cases out of 100 the estimated power requirement is that which is needed to operate the machine after it is running and the wider pulley has been provided by the machine manufacturer so as to insure the installation of a drive capable of taking care of the starting loads which are so much greater than the normal running loads.

If the clutch is not made large enough to handle the starting loads it will not properly function and it will be a constant source of annoyance, not through any fault of the clutch but because of its being called upon to deliver more than its capacity.

Mechanical Engineer, K. W. KNORR.
Dodge Mfg. Corp.,
Mishawaka, Ind.

* * * *

In reply to the query by E. E. H., the horsepower of lineshafts is computed from a general formula, depending on the location of the bearings. For example, if there are no bearings to take into consideration the horsepower transmitted by a shaft is equal to the cube of the diameter multiplied by the r.p.m., and the result divided by 50. This will give E. E. H. a better idea of why horsepower corresponds to the speed of the shaft. As for example, assume that a 4-in. shaft (this is for simplicity in illustration because the standard shaft diameter would be 3 $\frac{15}{16}$ in.) operates at the respective speeds of 10, 50 and 100 r.p.m.

According to the above formula the respective horsepowers are:

(1) $4\times4\times4\times 10\div50= 12.8$ hp.

(2) $4\times4\times4\times 50\div50= 64$ hp.
(3) $4\times4\times4\times100\div50=128$ hp.

However, if bearings are to be taken into consideration they are usually considered as existing every 8 ft. and the formula becomes: cube of the diameter, multiplied by the r.p.m. and divided by 75 (instead of 50). A common-sense allowance is made, in addition, for bearing spacing other than the 8 ft. mentioned above.

Aside from shafting, one has to take into consideration the gear speed, pitch of gears, and kind of gears, which range from ordinary gears to cast steel and double herringbone gears running in oil. Consideration must be accorded to the type of drive from the shaft, which may be rope, belt or chain with their accompanying limitations in speed and ability to transmit power.

The chief reason for using rope drive is its economy and ability to transmit power at a distance and at an angle; the amount of power that can be transmitted is limited by the number of ropes. Considerable speed is possible with rope drive.

Belts have the advantage of being able to operate in moist and hot places and have a flexibility of control and a versatility of employment that make them adaptable to temporary or permanent installations. Their thickness and width determine the horsepower and inversely, the speed.

Pulleys have the general limitation of their peripheral speed and the general action of centrifugal force; this also applies to clutches, couplings, and so on, and in general their requirements are such as to approximate the strength of an unbroken shaft without danger of breakage from centrifugal force.

The efficiency of a clutch at any speed depends on its alignment, a point which is often overlooked and seldom checked. This applies to all speeds. One must also consider that a clutch operating at a higher speed picks up its load in foot-pounds per r.p.m. at the same proportion as does the same clutch operating at a lower speed with corresponding lower horsepower delivered.

Any clutch that "grabs" the load should be hoisted about as far from the plant as the junk man can carry it, and the sooner the better. I have a very vivid recollection of such a clutch letting go just as I opened a plant door on a visit, and with the door approximately one-quarter open a ⅝-in. bolt struck it. The remainder of the clutch was wonderfully distributed about the power house, fortunately without damage. But from that day I have maintained that that is no way to greet a visitor. That experience taught me to be skeptical about an imposing entrance to any place containing transmission machinery. This particular clutch was a "load grabber" and ended as all such clutches are wont to do. Conditions and not allowance was responsible, since the clutch was oversize.

A good idea of a load pick-up can be obtained by watching the magnetic clutch pick up its load. The manufacturer uses a switch to control the action of the clutch and valuable information can be had on this type of clutch by addressing the manufacturer.

I appreciate that the question asked by E. E. H. is a general one and I trust that the answer I have given him will prove of benefit, although there are many points to be taken into consideration in applying transmission equipment to a particular job or installation. When one is planning to replace old equipment or put in new installations, valuable data can be secured from any of the manufacturers of transmission equipment.

Newark, N. J. EDWARD JAMES.

* * * *

In reply to the recent question by E. E. H., the items of excessive wear due to high speeds and shock of starting are considered when determining the horsepower of a lineshaft or clutch, or at least they should be, when figuring the power for high speed, and a liberal allowance made. For shafting the use of formulas is recommended. Shafting transmitting torque may be divided into three classes according to the kind of stresses to which they are subjected:

(1) Shafts subjected to torsion.
(2) Shafts subjected to bending.
(3) Shafts subjected to torsion and bending.

Due consideration must also be given to shaft deflection both angular and linear, or in other words the shaft must be stiff enough for the purpose. In calculating shafting for pure torsion it it customary to use the following unit stresses:

Main power shafts—4,000 lb.
Line shafts with pulleys—6,000 lb.
Small short shafts, torsion only—8,500 lb.

The inch-pounds torque may be calculated from the following formula:

(1) $Hp. \times 63{,}025 \div r.p.m. =$ In.-lb. torque.

The size of shaft may then be determined as follows:

(2) (In.-lb. torque) $\div (0.196\times d^3) =$ Unit stress.

The above two formulas may be combined into one formula which will shorten the time of calculation:

Main power shafts, $Hp.=(d^3\times r.p.m.)\div80$.

Lineshafts with pulleys, $Hp.=(d^3\times r.p.m.)\div53$.

Small, short shafts, torsion only, $Hp=(d^3\times r.p.m.)\div38$.

No allowance is made for the weakening of the shaft by the cutting of a keyway. Keyways reduce the strength of a shaft in torsion about 18 per cent.

Shafting with bending stresses is calculated first by determining the bending moment and torsional moments separately, combining the two into one stress called "equivalent twisting moment," and then substituting this value in formula (2) as in.-lb. torque.

(3) $T_e=M+\sqrt{(M^2+T^2)}$

Where: $T_e=$ Equivalent twisting moment; $M=$ Bending moment; $T=$ Torsional moment. Assuming stresses of 6,000, 8,000 and 10,000 lb. per sq. in. is common practice in calculating equivalent torsional stress in shafting.

Shafting should not have an angular deflection of more than 1 deg. in 20 shaft diameters. It is good practice to add ⅜ in. to ⅝ in. to the shaft diameter for angular deflection.

$(583\times T\times L)\div(D^4\times G) =$ Angular deflection. Where: $T=$ Torsional moment; $L=$ Length shaft twisted in inches; $d=$ Shaft diameter in inches; $G=12{,}000{,}000$.

Shafting may also be subjected to linear deflection and when the stress is exactly between the two bearings the deflection may be calculated with the following formula:

[(Load in pounds) × (Span in inches)^3] ÷ [48×29,000,000×(Moment of inertia)]=Deflection.

According to good practice, shafting should not have a linear deflection of more than 0.01 in. per foot of length.

The use of a brake test is recommended to find the load that will slip the clutch at a given pressure per square inch of friction surface. This pressure varies from about 10 lb. to 100 lb. per sq. in. The greater the pressure the shorter will be the life of the friction material and other parts of the clutch. A pressure of 25 lb. per sq. in. is recommended for clutches of the type used with general transmission machinery.

The load required to slip the clutch can be determined with a prony brake or by securing the clutch to a stationary shaft having an arm attached to the loose member of the clutch and the weight hung from the end of the arm. After the shaft and clutch are ready for the test, arrange to have the right pressure applied to the sliding collar, when placing the clutch in gear to get the required pressure on the friction surface. After finding the weight that slipped the clutch, proceed to figure the power as follows. Assume that the lever is 4 ft. long, measuring from the center of the shaft to the center of the weight suspended on the end of the lever. The circumference of a 4 ft. radius will be 25 ft., less the fraction. Suppose the result of a test made with a 4 ft. lever showed that 300 lb. weight was required and say the speed of the clutch was 100 r.p.m. Assume, $A=$Circumference (approximately 25 ft.); $B=$Weight (300 lb.); $C=$ Revolutions (100 r.p.m.). Then $(A\times B\times C)\div33{,}000=22.91$ hp.

For those wishing to arrive at a safe rating for various speeds and figuring from the rate given at 100 r.p.m., starting with a speed of 200 r.p.m., a clutch having 10 hp. at 100 r.p.m. will have 20 hp. at 200 r.p.m. From the 20 hp. deduct 5 per cent. The power at 250 r.p.m. will be 25 hp.; from this deduct 10 per cent. For the next increase of 50 r.p.m. the deduction will be 15 per cent. Continue in the same manner to speed limit.

There are conditions that cannot be taken care of by the instructions given, such as heavy starting loads, pulsating loads, continuous service, and clutch to be placed in and out of gear at short intervals. For extreme conditions the information should be given to a competent engineer to decide the power of the clutch required to obtain good service. J. L. LEMLY.

Manager, Clutch Department,
W. A. Jones Foundry & Machine Co.,
Chicago, Ill.

Method of Cleaning Skylights and Windows.—In our plant we have a serious problem in connection with the cleaning of skylights, transoms in monitor roofs and above the first floor, large windows with steel sash. I wish some readers would tell me what solutions they use for such cleaning, and describe any easily-constructed scaffolding or other method which they use to get to this large area of glass. This has been a very expensive and unsatisfactory procedure with us so far and I would like to know what others do.
Indianapolis, Ind. J. F. H.

Replying to the question asked by J. F. H., we have had experience with all kinds of acids and solutions, but the best thing that I have come across is "Skybryte," which is a solution manufactured by the Skybryte Co., Cleveland, Ohio.

I do not know the exact ingredients, but I do know that it does not injure paint or metal work.

I would suggest that J. F. H. have this manufacturer send a representative, who will not only give him information in regard to the solution, but will also give him practical information regarding the scaffolding, which he also requests.

Cleveland, Ohio. J. E. KALIS.

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Answering J. F. H.'s query regarding the cleaning of windows set in steel sash and located above the first floor, the difficulty of reaching them may be overcome by installing a monorail track at the coping of the building and suspending from this a car designed for the purpose. At first thought this may seem to be a round-about way to perform this job, but at several power plants where the writer has seen this system used, its first cost has been soon offset by the savings made. The car is so arranged that it can be either raised or lowered by hand power or by a motor drive, and a similar arrangement is used for propelling it around the building.

Master Mechanic, B. C. SCHLEGEL.
The Mechanical Rubber Co.,
Cleveland, Ohio.

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Calculation of Rotor Winding for Squirrel-Cage Motor—I have a 1-hp., 220-volt, Type RI, single-phase, General Electric motor, which I wish to rewind for three-phase operation. I have calculated the winding for the stator, but do not know how to go about figuring the squirrel-cage winding for the rotor. Can any reader give me some help in this matter?
Oakland, Calif. B. B.

Regarding B. B.'s question, the best method to follow in this case is to use the old rotor winding as a base. In all repulsion-starting types of motors, the rotor winding is short-circuited at a certain speed. After this stage the rotor acts as a squirrel-cage winding, having the correct distribution of current to provide the required running and pull-out torque, with a certain per cent of slip.

The first step in changing the wound rotor for three-phase operation, is to remove the brush rigging and short-circuiting device. The latter includes all springs, weights, and the copper necklace, when used. Next, turn and polish the commutator, put a bronze wire band on this clean surface, and solder it to the commutator. On radial commutators the band will have to be put on the narrow width of the necks so as to obtain a substantial job.

The above procedure will give the same results as a squirrel-cage winding and if greater starting torque is required the turns per coil and size of wire can be varied. More turns of a smaller size of wire will increase the starting torque and increase the full-load total losses, while less turns and a larger size of wire will decrease the starting torque, increase the starting current and decrease the full-load losses. If it becomes necessary to rewind the rotor, due to a burned-out winding, or to change the starting torque, the commutator can be removed from the rotor and the ends of each coil connected together, so that each coil becomes a short-circuited loop.

When rewinding, consider the coils per cell as being all in parallel. For example, assume a rotor having 37 slots and 111 commutator bars or three single coils per cell, each coil consisting of three turns of one No. 12 d. c. c. wire. Now when the rotor is short-circuited, the three coils are in parallel or equivalent to 37 coils, each consisting of three turns of three No. 12 d. c. c. wires in parallel. This point should be remembered when rewinding in order to change the torque and will enable B. B. to meet any starting conditions with a suitable winding.

Wilkinsburg, Pa. A. C. ROE.

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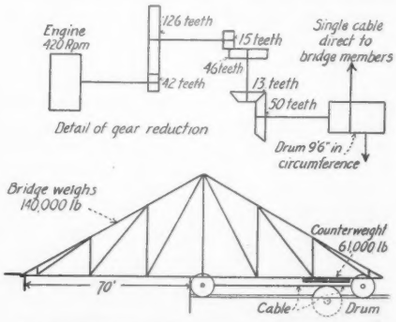
Size of Motor Required to Operate Drawbridge—I wish to know how to determine the size and speed of motor required to operate a drawbridge that is now operated by a steam engine. The diagram shows the general layout of the bridge. It weighs about 140,000 lb. and travels 70 ft. in 45 seconds. It is supported on four steel wheels 30 in. in diameter with a 12-in. face, running on steel rails. The bridge is pulled back and forth by a steel cable running on a drum which is driven by the engine through a gear reduction; this could be changed to a worm gear



if necessary. The speed of the engine is 420 r.p.m. while the drum turns at 10 r.p.m. I do not know the horsepower of the engine, nor is it equipped to take an indicator card, but the following data may help: Duplex engine (both cylinders receive same pressure); steam pressure, 50 lbs. per sq. in.; cylinders 8 in diameter by 10-in. stroke; speed 420 r.p.m.; non-condensing.

It will be necessary to use a two-phase, 60-cycle, 550- or 2,200-volt motor. I shall be very grateful for any help readers can give me.
Quebec, Que., Can. W. S. B.

Replying to W. S. B., the power required to propel a drawbridge weighing 140,000 lb. plus the weight of a counterweight of 61,000 lb. can be determined from the formula:

$Hp.=(W\times L\times S)\div(33{,}000\times e)$.

Where W=total weight of structure in tons (201,000÷2,000).

L=lb. per ton friction (assume 30).

S=speed in feet per minute.

e=Combined efficiency of gearing, rope friction, etc., say 0.8.

If the speed of the drum is 10 r.p.m., and the circumference is 9.5 ft., the speed of the bridge is 9.5×10=95 f.p.m.

Therefore, $Hp.=(201{,}000\times30\times95)\div(33{,}000\times0.8\times2{,}000)=10.8$ hp.

It should be noted that the above calculation is made on the assumption that friction is on the basis of 30 lb. per ton. If the wheels bind on the rails this value may be 60 lb. instead of 30 lb., and the horsepower required to propel will be twice as much.

To determine the horsepower rating of the motor, a rule of thumb method is to multiply the horsepower required to propel by two, and use the nearest standard rating. In this case 10.8 hp.×2=21.6 hp.

A 20 hp. motor should be about right. The reason for multiplying by 2 is because a heavy structure, like a bridge, with large inertia may require a large amount of power to accelerate it although a comparatively small amount is required for propelling it after it is up to speed.

A closer check, taking account of the WR² values of the different masses being accelerated would be as follows:

WR² of bridge=(201,000÷0.8) × [95÷(2×3.1416×810)]² ....= 87.5
WR² of gears and other rotating parts (assumed).....= 2.0
WR² of rotor of motor.....= 15.0
Total WR² of all moving parts referred to motor pinion.....104.5

Assuming the bridge is up to speed in 5 sec., the torque required of the motor for acceleration is only:

(104.5×810)÷(308×5)=55 lb. at 1-ft. radius.

The torque for propelling plus the torque for acceleration is 70+55=125 lb. to be exerted by the motor when bringing the bridge up to speed, where the propelling torque is (10.8×5,250)÷810=70 lb. at 1-ft. radius.

A 10-hp., 900/810=r.p.m. motor has a full-load torque of 65 lb. and a maximum starting torque of approximately 135 lb. Allowing for loss of torque due to low voltage, this value would be considerably less and under winter conditions when friction is high due to hard grease and presence of snow and ice, a motor of this size probably would not be able to break the static friction and get the bridge moving.

A 20-hp., 900/810-r.p.m., slip-ring type, crane motor will be able to exert a maximum torque of approximately 260 lb., or a little more with normal voltage and frequency applied at the motor terminals. This seems quite a margin over 125 lb. figured above, but besides the possibility of a higher friction than 30 lbs. per ton there is always the possibility of low voltage. The torque varies as the square of the voltage, so that if the voltage happens to be 490 volts instead of 550 volts the maximum torque becomes 260×(490÷550)²=207 lb., which does not leave as great a margin for acceleration as is the case when full voltage is present

on the local power company's system.

If either 550-volt or 2,200-volt power is available, I suggest the lower voltage, as a much better proposition can doubtless be secured from the motor manufacturer on both motor and control equipment.

A 900-r.p.m. (synchronous speed), crane-type motor is suggested. This is a standard 60-cycle speed and lends itself satisfactorily to gearing. A higher-speed motor would be cheaper but less satisfactory as far as gearing is concerned.

With a speed of 10 r.p.m. at the drum, the speed at the 42-tooth pinion will be $10\times(50\div13)\times(46\div15)\times(126\div42)=354$ r.p.m.

This is somewhat lower than the speed given by W. S. B. as the speed of his engine is (420 r.p.m.). Since the motor speed is going to be a little more than twice the engine speed, the 42-tooth pinion should be replaced by one having a smaller number of teeth; or assuming 810 r.p.m. is the correct operating speed of the new motor, $42\times354\div810=18$-tooth pinion.

R. F. EMERSON.

Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

* * * *

Answering W. S. B. regarding size of motor required to operate a draw bridge, the data furnished are not complete enough for an accurate estimate of the power requirements. From the cut, it is assumed that the bridge weighs 140,000 lb. and the counterweight 61,000 lb., making a total of 201,000 lb. or approximately 100 tons to be moved. From the unequal distribution of weight on the wheels and the general character of the installation, we will assume the rope pull required to move the bridge on a level track with no wind as 45 lb. per ton. It is further assumed that the time required to move the bridge must remain approximately as before and allow 5 sec. for acceleration and 5 sec. for coasting to stop or an equivalent rate of 70 ft. in 40 sec., or $(60\times70)\div40=105$ ft. per min. For convenience, let us take the bridge speed as being 100 ft. per min. Then using the formula $Hp.=(W\times f\times S)\div33{,}000$.

Where $Hp.$ = rating of motor in horse power

W = weight of bridge to be moved

f = friction in pounds per ton to drive bridge.

S = free running speed of bridge in feet per minute

From this we have:

$Hp.=(100\times45\times100)\div33{,}000=13.6$. The next commercial size above this would be 15 hp.

The work of accelerating the bridge from rest is found from the formula:

$Hp.=(W\times S^2)\div31{,}680\times0.85\times t$

Where W and S have the same values as in the previous formula and t = time in seconds taken to accelerate the bridge from rest to full running speed, which we assumed above at 5 sec. then,

$$Hp.=(100\times100^2)\div(31{,}680\times0.85\times5)=7.4$$

This figure combined with the 13.6 hp. found from the first formula would indicate that a 20-hp. motor would be required in this particular case.

The drum being 9 ft. 6 in. in circumference would be almost exactly 3 ft. in diameter. At a uniform bridge speed of 100 ft. per min. the drum would be revolving at the rate of $100\div9.5=10.5$ r.p.m. Selecting a motor running at 870 r.p.m. the gear reduction would be $870\div10.5$ or 83 as against 40 in the existing installation. This change in over-all gear ratio would, of course, have to be taken into account in redesigning the installation. A Westinghouse 15-hp., 870-r.p.m., type CI motor has a rated torque at 1 ft. radius of 95 lbs., whence the torque at 1 ft. radius at the drum would be 95×83 or 7,880 lbs. or $7{,}880\div1.5=5{,}250$ lbs. rope pull at 100 per cent efficiency. The actual rope pull required with no wind under the above mentioned assumption of 45 lbs. per ton is, $45\times100=4{,}500$ lb. This would allow an efficiency of the complete gear train of $4{,}500\div5{,}250$ or 86 per cent.

This is quite high as the efficiency of such machines rarely runs over 70 per cent and since no allowance was made for wind load it would probably be advisable to install at least a 20-hp. motor, which is rated at 125 lb. torque at 1 ft. radius. This latter rating then would check fairly closely with the combined requirements of acceleration and propulsion. This would give 6,900 lb. theoretical rope pull and would allow $4{,}500\div6{,}900=65$ per cent efficiency for the gearing. The maximum starting torque for this motor is 230 lb. and the maximum running torque is 288 lb. so that considerable leeway is available for wind loads and unknown factors. Such a motor would have a wound rotor and would be a ½-hr., 50-deg. C. rating.

If wind load is to be considered, allow 10 lb. per sq. ft. of projected area in the direction of travel and add this to the tractive effort of 4,500 lbs. required with no wind and compute again, using the following formula $T=(5{,}250\times hp.)\div r.p.m.$

Where T = torque on motor shaft in lb. at 1 ft. radius.

$hp.$ = rating of motor desired

$r.p.m.$ = revolutions per minute of motor shaft.

If a worm reduction gear is used the size of the motor would have to be increased still farther, as the efficiency of worm gearing goes as low as 20 per cent. However, there might be some advantage in a low-efficiency worm gear, as in general the lower the efficiency the more nearly self-locking the worm becomes, and hence less braking is required. It is standard practice to use shunt-wound, magnet-operated brakes operating on the shaft of the motor. The brake torque should be equal to or greater than the full-load torque of the motor used and should be capable of holding the bridge still against a wind force of 30 lb. per sq. ft. of projected area. A reversing three- or five-point drum controller with separately mounted resistor should be used and it might be advisable to install a track limit switch also, depending upon the local conditions.

If the above assumption as to total weight of bridge is erroneous and the total including counterweight is only 140,000 lb. the motor rating should be reduced correspondingly.

For a rough check on the size of motor, selected above take the steam engine as it stands and assume a m.e.p. of 22 lb., which is probably high, and therefore the rating obtained below is correspondingly high. Using the well-known formula $Indicated\ hp.=(P\times L\times A\times N)\div33{,}000$ and neglecting the area of the piston rod, we have

$$Hp.=[22\times(10\div12)\times3.14\times4^2\times2\times420]\div33{,}000=23.4$$

From this formula we obtain 23.4 hp. per cylinder or a total of 46.8 as the indicated horsepower of the two cylinders. Assuming a mechanical efficiency of 85 per cent for the engines alone, we would have $46.8\times0.85=39.8$ hp. available at the engine shaft.

This is practically double the size of motor selected above but, as already pointed out, this is probably higher than the actual output of the engines. Then, too, data not being at hand to compute the power required to overcome wind pressure, it may be that the 20-hp. motor selected would not be large enough to take care of this wind load. On the other hand, since the maximum running torque of the motor is over twice the rated running torque, this motor could easily deliver 40-hp. for the 45 sec. it would be in operation, without a dangerous temperature rise.

Fort Worden, Wash. E. I. PEASE.

* * * *

Method of Cleaning Motor Winding—What is the best method of cleaning motors that are oil-soaked and dirty? Can they be washed in gasoline and baked out in a bake oven to any advantage? What is the best method of handling the gasoline? Should the armatures be dipped in a trough containing gasoline, or should they be wiped with a gasoline-soaked rag? I would greatly appreciate hearing of any other methods used by readers for cleaning oil-soaked windings, as well as the results obtained by using gasoline for cleaning.

Chicago, Ill. R. W. A.

R. W. A. asks for the best methods of cleaning motors that are dirty.

In cleaning large motors it is best to first remove the heaviest part of the grit and dirt with a coarse brush; if it is just loose, heavy dust a coarse hair brush will be best. In any case the heaviest part of the dirt should be removed before applying any cleaning fluid, as it will be difficult to remove the grit and dirt after they have been moistened. After the heavy dirt has been removed, wipe carefully in and around the windings, especially around the windings next to the frame of the machine with a piece of cheese cloth dipped in gasoline. A common paint brush dipped in the cleaning fluid will prove very satisfactory in cleaning the oily grit that is usually found in the windings next to bearing housings.

In using gasoline, I would suggest that R. W. A. be very careful as to the amount he uses, as it is a well-known fact among maintenance men that under some conditions gasoline will tend to cause the insulation on the

windings to become brittle and crack.

I have found that the use of carbon tetrachloride is very satisfactory for removing oil and grit from the windings. As a matter of fact, it will do a better job of cleaning than will gasoline, and will evaporate very rapidly, before it has a possible chance to soak into the windings, thereby making it unnecessary to put the motor in a bake oven to be dried out. When the motor can be left out of service for a few hours and can be put where the sun can shine on the windings, I think it will be found that cleaning can be done without injury to the insulation.

I do not think it is advisable to dip the windings into a vat or container of gasoline to remove the oil and grit, for the reason stated above. If the entire winding is dipped in any cleaning fluids, a thorough drying out will be necessary.

If it is possible to obtain compressed air or vacuum, it would be better to remove the loose dirt and dust in this way, as both of these methods, suction or blowing, have proven very satisfactory and are recommended by many of the manufacturers of motors and generators.

When cleaning small machines a paint brush and cloths with some kind of cleaning fluid will be found to be the most satisfactory.

I hope that R. W. A., as well as other readers of INDUSTRIAL ENGINEER who may be planning a cleaning expedition, will find the above information useful.

F. J. H. KRAUSE.

Power Maintenance Division,
Southwestern Bell Telephone Co.,
Dallas, Tex.

* * * *

Answering R. W. A., I have never dipped an armature for cleaning and do not feel entirely competent to express an opinion on this method of cleaning. If no other method was possible I would resort to dipping, but in my experience I have always found a different way to clean everything from small jobs up to water and steam turbines of good size.

I find that many repair men use waste for cleaning with gasoline. For my part I have found a putty scraper useful for flat work, using hacksaw blades and the like for other parts (and be sure that they are all present or accounted for when the job is completed). I supplement these with stiff bristle brushes ranging from tooth brushes and paint brushes to those with stiffer bristles, and use hard rags for absorbing and wiping in preference to waste.

Generators can be driven by the prime mover and dried by circulating an idle current through the windings. As a matter of fact, I have always tried to arrange cleaning for such times as will allow the generator to be idle and permit thorough evaporation of the gasoline. This will allow the use of the generator for a short period without varnishing windings and serves to dry them out completely before varnish is applied.

I have found no bad results from use of gasoline, and have also used kerosene and benzine in the same way.

The application of the gasoline depends upon the apparatus to be cleaned. For small places and small jobs I have applied it with a blow torch. For larger jobs I have used it in connection with an air supply of approximately 40 lb. per sq. in. It is possible to use too much and if too small an amount is used it resolves into a very dirty, smeary mud.

Newark, N. J. EDWARD JAMES.

* * * *

In reply to R. W. A., excellent results in cleaning motors may be obtained by carefully wiping off with rags well saturated with gasoline. Armature and field coils, which were well covered with an accumulation of oily dust and dirt have in this way been put in satisfactory condition for revarnishing.

If the windings are really oil-soaked, as R. W. A. states there is hardly any process which will remove the absorbed oil. In most cases, however, the oil is merely on the surface, and unless the varnish has been charred or cracked, the treatment mentioned will prove satisfactory.

It is well to use a high-test gasoline for this work, as most of the ordinary gasoline has a noticeable oily or greasy content. Be sure that the gasoline has entirely evaporated before starting the motor if it is of the commutator or slip-ring type.

The re-varnishing referred to above should follow a thorough air-drying of the cleaned motor. Use a spirit varnish for this purpose so that grease or oil will not dissolve it and penetrate into the winding. When cleaning with gasoline, if the varnish comes off with the dirt and grease, one may well suspect that the oil has gone through to the windings. This is the result of using a gasoline or benzine varnish for the final outer coating.

Asst. Chief Engineer,
Gurney Elevator Co., J. M. WALSH.
New York, N. Y.

* * * *

In reply to R. W. A., there are several good methods of cleaning stators. If the stator is very dirty and oily one method is to wash with gasoline under pressure. An ordinary paint spraying appliance, such as the small portable type used for painting armatures and motors, may be used to advantage. After washing the stator in this manner it should be thoroughly heated and dried out in order to remove such oil and moisture as has penetrated the insulation of the coils. The time taken for this drying process will vary with the condition of the motor; some motors require only 8 or 10 hr., while others require from 24 to 48 hr. This applies to relatively small motors, 100 hp. or under. Larger motors will require more time in proportion.

Another very good method that, while it is a little more expensive is very efficient, involves the use of a regular cleaning fluid such as the cleaning fluid put up by the manufacturers of Pyrene. If this cannot be obtained readily, the regular Pyrene extinguisher liquid may be used. This liquid is an excellent cleaner and evaporates very rapidly. It is safe to use, so far as danger of fire is concerned, but the fumes given off are very offensive and cleaning should be done where there is a plentiful supply of fresh air; otherwise the operator will be made very uncomfortable.

A method which has been used to some extent, but has never met with the approval of very many electrical men, makes use of water under pressure. It has been used on motors that were filled up with dust not containing oil. If an excellent drying oven is available this method may be used with some success, but in my opinion it is best to keep away from the use of water or any other liquid which is slow to evaporate.

If handled by a careful operator, an ordinary, coarse scrubbing brush and a pail of gasoline can be made to give excellent results. After the washing, compressed air can be used to clean out the air ducts, which are usually plugged up. During the past two years the writer has been using a spray gun and gasoline under a pressure of 40 to 80 lb. per sq. in. The pressure used depends upon the condition of the insulation of the coils. If the insulation is old, low pressure must be used; otherwise the tape will be torn off the coils. If the insulation is in good condition and has not been subjected to very much oil, 80 lb. pressure may be used without damage to the tape. We dry the motors out thoroughly before and after cleaning and then give them one or two coats of Sterling black air-drying varnish.

In many old motors where the bearings have been rebabbitted in the plant shop, no provision is made to drain oil from the bearings back into the oil well; consequently it follows the shaft and is blown all through the coils by the fans on the rotors. All sleeve type motor bearings should have a groove cut around the inside at each end and small holes drilled at the bottom to allow oil to drain into the well, instead of following the shaft.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

In answer to R. W. A., regarding methods of cleaning oil soaked motors and windings, we use a gasoline spray gun that can be bought in any automobile accessory store. This gun is used with an air pressure of 60 to 80 lb. per sq. in. The gasoline is contained in a bucket. A hose attached to the gun dips into the gasoline and serves to conduct it to the gun. The latter is provided with an adjusting screw so that the spray can be regulated as desired. We get very good results by the use of this outfit.

One of the chief advantages is that the windings do not become soaked with gasoline, as in the case when they are dipped. Soaking in gasoline has a tendency to injure the insulation of the coils.

When applied by the spray gun, the gasoline evaporates very quickly. When the windings are dry, it is a good idea to coat them with a good air-drying insulating paint or varnish. This should be allowed to dry thoroughly before the motor is put back into service.

Chief Electrician, H. CHARLTON.
E. I. du Pont de Nemours & Co.,
Newark, N. J.

Electrical Service

around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

How an Emergency Contactor Was Made From a Hinge

IN AN emergency, a novel expedient was used to provide a direct-current contactor for a control panel. The contactor which had been in service was so badly burned and worn that it would no longer function. Failure occurred on a Saturday morning, and the motor on which the control was used was needed for emergency work all that afternoon, that evening and the next day. No other contactor was available. On searching through the shop an old strap hinge and a few other parts were discovered, including a 230-volt contactor coil. The coil had an iron core, one end of which was tapped for a 10/24 machine screw. We conceived the idea of making up an emergency contactor from these parts.

The iron pin holding the two parts of the hinge was removed and a brass pin substituted so as to keep down as much as possible any magnetic drag which might exist at the hinge point. The space between the two sections of the hinge was increased sufficiently to allow the insertion of brass washers to keep the two halves in line and also to prevent an iron to iron contact that would cause a magnetic drag. One half of the hinge was bent at right angles, as indicated in Fig. 1 and one of the holes originally intended for a screw was used to hold the coil fast to this half of the hinge. The remaining holes in this half were used to bolt the completed contactor to the base. Fig. 2 shows what each screw hole in the hinge was used for.

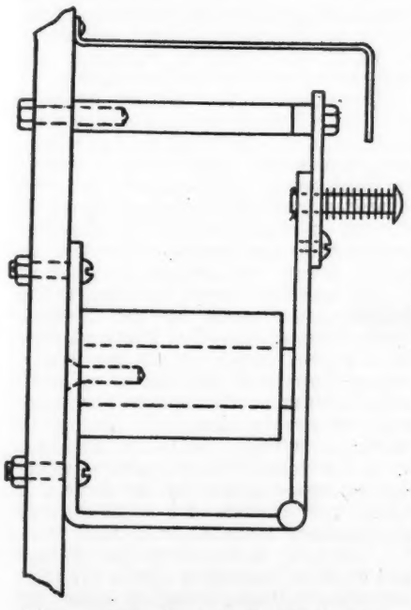


Fig. 1—One strap of the hinge was bent as shown to form the frame of the contactor.

The other strap formed the armature. A contact held by a spring is fastened to the end of the armature. The stationary contact, with which this engages, was made from brass rod ⅛ in. in diameter.

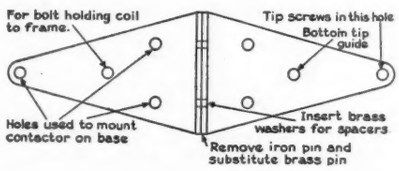

For bolt holding coil to frame.
Tip screws in this hole
Bottom tip guide
Holes used to mount contactor on base
Insert brass washers for spacers
Remove iron pin and substitute brass pin

Fig. 2—The iron hinge pin was replaced with a brass pin to reduce any magnetic drag that might exist.

Brass washers were inserted as indicated between the edges of the straps where they rub against each other at the hinge point. The screw holes in the hinge straps were utilized in forming the contactor, as is shown in the diagram.

The other half of the hinge was used as an armature and a pin was placed in the outermost hole to hold the contact in place by means of a spring, as shown in Fig. 1, and thereby allow a small amount of wipe on the contact points. This spring also aided gravity in pulling the armature away from the coil when the contactor opened. The hole in this half of the hinge, which corresponds to the hole in the other half used for holding the coil in place, was used to hold a pin which kept the contact fastened to this half from moving sideways. The movable contact was carried on a piece of flat brass about ⅛ in. thick and ½ in. wide which was bolted to the top of the armature as shown in Fig. 1.

For the stationary contact tip a piece of ½-in. diam. brass rod was used, one end being drilled and tapped and a screw inserted to hold the tip rigid on the base as shown in Fig. 1.

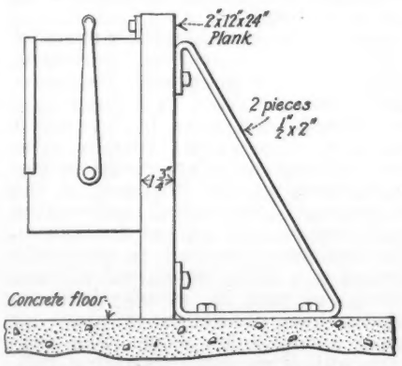
As the contactor was to carry only 7 to 10 amp. a flexible shunt was soldered to the brass piece, carrying the movable contact tip, and was run to a stud on the panel. A strip of brass was bent, as indicated in Fig. 1, to act as a stop, thus preventing the armature from dropping out too far when the coil was de-energized. Adjustment was provided on the stationary contact post so that the proper travel of the armature might be obtained and, at the same time, a sufficient amount of wipe be provided.

No blowout or arc chute was used. There was a small amount of arcing, but during the three days the equipment operated no seriously harmful effects were noticed and, at the end of that time, the contactor appeared to be in very good condition.

Industrial Control Dept., E. B. SMITH.
General Electric Co.,
Cleveland, Ohio.

Mounting Motor Starter Without Defacing Building

IT IS not until a room is completely stripped of machinery and other equipment that the extent of the defacing and mutilation of the building, due to the erection of the machinery and its auxiliary equipment, becomes apparent. Then for the first time the plant man sees the grooves in the floor, which were cut by trucks, holes which were gnawed in the floor by loose machinery fastenings, posts hacked and studded with nails, and ceiling members which are split at the holes bored in them to suspend various fixtures. These mutilations, which would ordinarily not be noticed, are very obvious when there is not the usual equipment around to overshadow them. Cement floors are subject to more mutilation than wooden floors because the latter are more easily patched and so are generally repaired whenever torn up. Some of these defacements can hardly be avoided. However, what might be termed minor defacements, which are generally due to the installation of small machines or auxiliary equipment such as starters, switches and so on, are generally more numerous and frequently show up more prominently as well as do more permanent



This substantial mounting for a motor, compensator or other auxiliary control equipment may be placed wherever convenient and causes little mutilation of the floors.

damage to the building. More care to prevent this would need to be taken where the equipment in buildings is shifted frequently as otherwise the interior would soon be almost entirely defaced.

The method illustrated on the preceding page for mounting supports for compensators, motor starters, switches and other similar auxiliary equipment, not only provides a substantial mounting but causes very little defacing. Use is made of a piece of 2-in. plank of any length and width necessary. This plank is dressed all over and is held upright by two triangular brackets, which are fastened to the back and secured to the floor by four ½-in. bolts or lagscrews. The starter, or other auxiliary equipment, may be mounted as shown. Such a type of mounting does not deface the floor and is frequently much more convenient than mounting the equipment on a column or wall, which can seldom be done without leaving some defacing mark. Installations of this type may be used for mounting the auxiliary control equipment around wood-working machines, presses, textile machines and other equipment.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

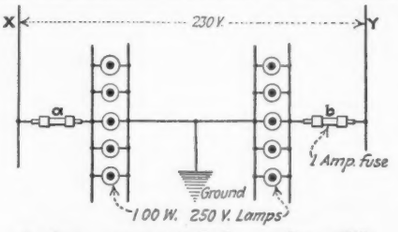
Methods of Testing for Grounds and Faulty Insulation

INSULATION is by far the weakest link in the electrical chain. Failure of it results either in shorts between conductors or shorts between a conductor and an adjacent conductive material, causing a ground. A single ground produces no excessive current flow but subjects the remaining sides of the circuit to an increased potential, which increases the strain on the insulation of this side of the circuit, thereby making an insulation failure at this point more probable. An additional ground, occurring from this or other causes, creates a current flow which, even if small proportionately, soon burns through, making a heavy ground.

Many grounds occur suddenly by overheating and burning, fires, water soaking, damaged insulation, dirt, and the like. Most grounds are produced more slowly by the gradual deterioration of the insulation, although this weakening may be the development of the same causes.

Grounds in electrically-operated plants cannot be entirely prevented. Systematic testing of the insulation throughout the plant well repays the operator in the form of a marked reduction of electrical trouble. The first concentrated effort should be frequent tests of the condition of the insulation. One method quite often used involves the use of a magneto. The magneto, however, is practically limited to a rather rough test of insulation, because it merely indicates whether the insulation is above or below a certain low value. The magneto will often give misleading indications on circuits having even a small electrostatic capacity. Under such conditions it will indicate a short-circuit, even though the insulation resistance may be high. Likewise, the magneto may indicate an open circuit when the circuit is not open. For example, if the magneto is used to ring out a shunt-field coil of a direct-current motor, the bell will not ring, owing to the high induction of the coil. The natural inference would be that the shunt-coil is open. Testing with a magneto in this particular case would not be conclusive.

If regular tests of all circuits are made when the machines are idle, with an insulation testing device such as a megger or megohmer, the condition of the insulation can readily be noted and recorded. By comparing the values of insulation resistance obtained with those taken on previous tests, a good idea of the condition of the insulation may be obtained. Evidence of deterioration gives a warning sufficiently in advance to allow ample time for repairs.



A fuse, connected in series with the ground detector lamp, blows when a ground occurs.

By using ten 100-watt, 250-volt lamps connected to a 230-volt circuit as shown, a current of 0.92 amp. is normally drawn from the line. This is not sufficient to blow the 1-amp. fuses shown at *a* and *b*. In case a ground occurs on one side or the other of the line, one bank of lamps is subjected to full line voltage, thereby raising the current through it to 1.84 amp. and blowing the fuse.

Much time can be saved during such testing by closing all switches and testing at the bus bars. Should this group method show up serious trouble, the general location of the fault can then be determined by eliminating, consecutively, sections of the system. This method is particularly valuable for testing the bus, switch gear, distribution cable, transformers and other large equipment.

As previously indicated, this method is not a cure-all and should be augmented by tests for actual grounds during the operation of the equipment. A ground at one point of a system shows on all units directly connected into the system at that time. Familiarity with the period and cycle of operation of various machines gives, in many cases, a good idea as to the location of the trouble by its effect at the center of distribution. A multiplicity of equipment of similar operating characteristics, however, requires more thought and more splitting-up during the test.

Lamps or voltmeters arranged for permanent or multiple connections from bus to ground, are frequently used as ground indicators. Use of this method requires that someone be watching the voltmeters or lamps at the particular instant that the ground comes on. For that reason, this method is very limited, as many grounds will occur unnoticed, particularly those of more or less intermittent character.

Various connections of lamps or resistors with fuses, as shown in the accompanying diagram, overcome this objection to some extent, but not entirely. In the case illustrated, two sets of five 100-watt, 250-volt lamps are connected in series across the 230-volt supply. The connection between the two sets of lamps is grounded. Fuses of 1-amp. capacity are connected in series with the lamps at *a* and *b* as shown in the diagram. Under normal operation using 250-volt lamps on a 230-volt circuit, a current of 0.92 amp. would be drawn through the fuses by the lamps. This is not sufficient to blow the fuses. In case a ground occurs on either side of the line, one set of lamps will be subjected to full line voltage instead of half line voltage, thereby raising the current through that set of lamps from 0.92 amperes to 1.84 amperes. This current would blow the fuse for this set of lamps, thereby giving a permanent indication of a ground existing on the side of the line opposite that to which the fuse is connected. The writer has used this scheme with very good results. A non-renewable fuse will be found preferable for use at *a* and *b*.

The use of graphic meters, with the advantage of continuous records, appears to be the best method for detecting actual grounds. An excellent article by R. H. Bahney, describing the use of graphic meters on direct-current circuits appeared in the September, 1925, issue of INDUSTRIAL ENGINEER. The use of graphic meters on alternating-current systems may prove more complicated. If the electrical system consists of several banks of transformers without secondary tie lines it will, of course, be necessary to install and maintain at least one alternating-current graphic voltmeter on each secondary distribution circuit.

Other devices for testing grounds have their field of usefulness, due particularly to the fact that they are compact, handy and sufficiently accurate for quick work. The magneto is found in nearly every maintenance shop. It is most useful, however, in shooting trouble after the breakdown occurs. A handy device for testing for grounds as well as other circuit troubles, is the pocket tester made by the Electric Tester Mfg. & Sales Co., Portland, Ore. This pocket tester is of the multi-voltage type and consists of a small lamp together with suitable resistance and tap arrangement for testing all standard voltages, both a.c. and d.c. up to 600 volts. There is also a pocket voltage tester (made by the Square D Co.) which consists of a small solenoid and plunger mounted in a fibre tube. An indicator fastened to the plunger and working through a slot in the tube, indicates voltages ranging from 110 to 600 volts both a.c. and d.c.

A companion to these two for testing higher voltages is the spark gap tester, known to the trade as "Spark C" (made by the Westinghouse Electric & Mfg. Co.). This tester is generally used for testing the ignition system of

gasoline engines, and has the big advantage of safety in testing high-voltage circuits. It is not necessary to touch a live conductor. If the tester is brought close to a live conductor, the tube will glow. This glow will occur even through the ordinary cable insulation or porcelain insulator or other types of insulation. A conductor of zero or low potential will not produce a glow in the tester and thereby shows the presence of a ground, open or other fault disturbing the voltage balance of the system.

Grounds are frequently located by resistance measurements of the copper conductor from some accessible point to the grounded portion. For this purpose the Wheatstone bridge, or modifications of it have been used for many years.

In the repair shop, motors and other electrical apparatus are generally subjected to a voltage higher than rated voltage to determine the condition of the insulation. Should a weak spot be present, it is broken down and its location readily found. When followed by repairs, this practice saves considerable time, but in general the method is too destructive to be used about the plant, unless it is apparent that the apparatus will probably have to be taken from service for replacement with new equipment.

The size and layout of a given plant, together with the cost of production delays will greatly assist in determining which of these methods will be best. For this reason the various methods of testing have been compared with each other. R. N. VINING.

Electrical Engineer,
Detroit Seamless Steel Tubes Co.,
Detroit, Mich.

Inexpensive Way to Prevent Starting Shunt Motors on Weak Field

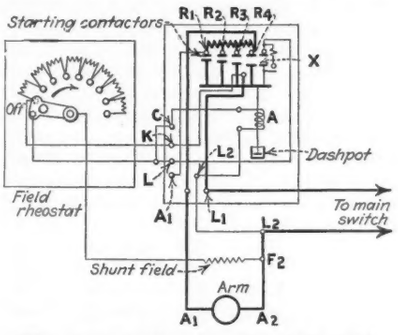
IN MANY plants where old-type, manually-operated, control is in use, a problem that often confronts the electrical superintendent is how the change to automatic control can be made without running up the maintenance costs; the management oftentimes considers that so long as the manual control is starting the motors, no change is necessary.

In some cases, when the idea of automatic control has been sold to the management and a quotation received from the control manufacturer, the price is found to be so high in proportion to that paid for manual control, that the change is pigeon-holed until the brighter days of better business. This being the case, it is sometimes necessary to do a considerable amount of figuring to obtain a satisfactory automatic controller and still keep the purchase price down.

As a concrete instance, I will cite a particular case where some money was saved. A 5-hp., 400/1600-r.p.m., 230-volt motor was used to drive each stoker grate in a large boiler house of a steel plant. The control installed with these motors consisted of standard starting and speed-regulating rheostats in which the contact arm is moved across the faceplate thereby cutting out the starting resistance and then moved back in the opposite direction to give speed control.

Considerable trouble was experienced with these starters, chiefly due to their being operated by foreign labor. After three or four years' operation there was little of the original starters left, and a considerable amount of money had been spent in keeping them operating.

In looking about for a new type of starting equipment it was decided that a time-limit acceleration starter, similar to those which had been installed on various drives in the plant, would



The first button on the full field side of the field rheostat was disconnected and connected through (C) to coil (A).

When the field rheostat is in the off or full field position it bridges the first two buttons, as shown. Power flows from *L2* through coil *A* to *C*, thence to the off button, then across the rheostat arm to *K* and to *L1*, thereby completing the circuit and causing the operating coil *A* to function.

be best for the conditions encountered in the boiler house. The only trouble with the time-limit acceleration starters was that no provision was made to prevent the operator from starting the motor with a weak field. Upon taking this matter up with the manufacturer of the starter, it was found that a field relay could be installed, but the price would have to be increased about 100 per cent, which made it prohibitive.

The starters were, therefore, ordered standard and the following scheme worked out to change them when received. The resistance was disconnected from the first stud in the field rheostat and connections made as is clearly shown in the accompanying diagram.

When the rheostat handle is turned to the off position, the operating coil *A* is energized from *L2* through *C* across the rheostat handle to *K* and to *L1*. Thus the coil closes the starting contactors and accelerates the motor. The operating coil circuit is maintained through an auxiliary contact at *X* which closes with the last main contact. The motor can then be speeded up at will by turning the field rheostat arm, thereby cutting resistance into the shunt field.

It will be readily seen that unless the rheostat handle is turned to the off position, the *A* coil circuit cannot be energized; therefore the starting contactors will not close to start the motor.

The starting or stopping of the motor is controlled by a switch ahead of the starter. In the case of power failure, if the rheostat is on the off position for low speed, the motor will start up; if in any other position, however, the operator must first turn the rheostat back to the off position before the motor will start.

This control as changed has been giving satisfaction for the last year and a saving of about $50 was made on each starter. O. C. CALLOW.

Chief Electrician,
The Trumbull Cliffs Furnace Co.,
Warren, Ohio.

Ammeter in Motor Feed Gives Control Over Quality of Product

IN THE drawing of heavy brass and bronze wire a double pull block is frequently used. This consists of a horizontal shaft with a block at each end on which the wire being drawn is wrapped after being pulled through the reducing die. In these days of increased production demands it is advisable to get as much output from each side of the machine as it can safely deliver.

In our case, the double block was driven by a 75-hp., 230-volt, General Electric, variable-speed, direct-current motor. To guard against burning out this motor, due to overload, we installed an indicating ammeter in the line to the motor. The maximum current which the motor could safely draw, was heavily marked in red on the ammeter. The operators were instructed to govern the amount of reduction of wire on the two sides of the machine so that the pointer on the ammeter would not pass the red mark. A rather liberal allowance of 50 per cent overload was made in locating the mark because the operation is intermittent.

Due to changes and expansion in the plant, we have arranged this block so that only one side is used and nothing but Phono Electric trolley wire is drawn on it. We now use the indicating ammeter to obtain greater control over the operation. It is still necessary to have knowledge of the current drawn by the motor when the block is speeded up because, naturally, more power is required for any particular draft with a higher speed, especially when working on this heavy wire.

We have determined, therefore, what speeds should be used on the different drafts of wire and what energy these different drafts should take. Any departure from the normal condition for any speed and draft, which might be due to a variation in quality of the alloy or other causes that would affect the quality of the wire, is indicated at once to the operator, as the ammeter is located so that he can easily watch it. This ammeter has been of great assistance to us in maintaining an even standard of product as it gives us almost laboratory control in the shop itself. E. R. FEICHT.

Plant Engineer,
Bridgeport, Brass Co.,
Bridgeport, Conn.

Mechanical maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Driving Pedestal Emery Grinder With Bevel Gears

FLOOR grinders such as are universally used for snagging, miscellaneous grinding, sharpening tools, and so on, are usually either belt driven or, if they are new, are of the built-in-motor type. In a machine shop manufacturing conveyors the type of drive was changed from lineshafting to individual motors. What to do with four belt-driven floor grinders was a question which bothered the operating force for some time.

These grinders were good, rugged machines, which were mounted on substantial pedestals, and had proven perfectly satisfactory; new motor-driven machines would run into considerable money, which was an expenditure hardly warranted by the circumstances. However, the master mechanic knew of no "past performance" that suggested any alternative, unless it was to put motors overhead and belt from them to the grinder pulleys. The construction of the machines was such that motors could not be installed between the bearings; at least, the shop did not have the equipment or the experience to do this.

The method of attaching direct drives to these old grinders was a somewhat novel one. However, it was sound fundamentally as is attested by over six years' continuous operation during which time not a single criticism has been entered in regard to these machines. The spindle pulleys on the grinders were removed and bevel gears put on the shafts in the place of the pulleys. A mating bevel gear was placed on the stub shaft of the motor which drives the machine. There is nothing radical about the drive, but many experienced shop men would immediately hold up their hands in horror, and say: "What? A gear drive, and bevels at that, running at motor speed? Why, you couldn't hear yourself in a room with one much less four of them running. Now, a worm —that would be silent; but of course you couldn't get the speed out of a worm drive."

The remarkable part of it is that these gears are not noisy. The machines make no more noise than they did when belt driven. Visitors to the shop often ask about the kind of a drive on those grinders because the grinders are conspicuous and are placed around the shop at odd places as they are moved anywhere that is convenient for use on an erecting job. Both the gears and the motors are enclosed with sheet-metal hoods to protect them from the dust from the grinding wheels.

Three of the machines run at 1,800 r.p.m. and one at 3,600 r.p.m. Current is supplied at 220 volts, 60 cycles from sockets arranged at fixed points for plugging in. A long extension cable is part of each machine's equipment.

The grinder shown in the accompanying illustration is driven by a 2-hp. motor which is supported on a metal frame on the back of the machine and is suitably braced from the pedestal. A lighter frame for mounting the starter is carried upwards. This places the starter in a convenient position between and above the two wheels. These frames are substantial but not elaborate. This machine has a pair of bevel gears 4 in. in diameter, eight-pitch teeth. They do not run in oil, but are merely greased once in a while, and they have not been renewed since installed. Miter bevel gears are used on all drives. This design has proved to be both durable and satisfactory and has saved what would have been a considerable investment in new grinders.

Plant Supt., DONALD A. HAMPSON.
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

The motor is direct connected to the pedestal grinders through miter bevel gears.

To obtain a more flexible arrangement of the machinery in one shop group drives were replaced by individual motors. The problem of connecting motors to each of four double-head pedestal grinders was solved by installing bevel gears on the grinder shafts which mesh with mating gears on the motor shaft. The motors are mounted at a right angle to the grinder shafts on brackets attached to the pedestal. This installation has operated satisfactorily for six years and saved a considerable investment in new machinery. These grinders are moved wherever they will be most convenient for the manufacturing and assembling operations.

Belt Maintenance Kinks Which Help to Avoid Trouble

LEATHER belting is one of the most extensively used means of transmitting power in the industrial world today and it is, therefore well to understand its proper care and operation, not only in the large plant, but in the small one as well. Belts respond to good treatment in any plant.

How many plants are not getting the full efficiency of their belts?, and How many are actually abusing their belting?, are questions worthy of note and careful consideration. A large number of cases investigated have shown that only a little, or no knowledge of leather belt maintenance is costing the users a large sum annually in power losses.

The general tendency seems to be to run belts tight, sometimes so tight as to pull countershafts and small equipment loose, and often breaking the belts or stretching them excessively. Because small belts usually give little or no trouble they do not present the problem that the larger ones do, from the load standpoint.

As engineer of a large concern, one of my duties consisted of the maintenance of over 1,700 leather belts from 1 in. wide, up to two large belts 6 in. wide. A large number ran tight and were always giving trouble, as no means had ever been taken to solve the load problem. For four years these belts were treated regularly with Cling Surface belt dressing, and during this period gave satisfactory service. Then a fire damaged the plant.

The engine room and two departments were flooded with water and after the fire was put out it was evident that the water had done the most damage. Many of the belts were supposedly ruined, but on closer examination we found only six belts under 2 in. wide were lost, and by fire at that. The remainder were practically unharmed, as the belt dressing was waterproof. Every one of these belts, with one exception, is running today under a slightly increased load. One

of the large 6-in. belts has been replaced by motor drives.

A few suggestions on the care of belts may help other plant men. A belt should never be put on the pulley with the skin side out as this has a tendency to break down the dressed surface of the belt and weaken the fiber, especially on a short bend. New belts should be treated with dressing sparingly until broken in. After once getting a belt in proper shape with the right treatment it should be run a little slack to get the best results, except on vertical belts which sometimes have to be snug but not tight enough to cause undue strain. These belts are often run to better advantage by using an idler or short-center drive to take up the slack.

Motor belts are often taken up so tightly as to cause undue heating of the motor and rapid wear of the bearings. Proper attention to the belt would avoid this.

Good belt dressing costs money, and many buyers prefer the cheaper brands. This policy of buying inferior dressing is a grave and expensive error in that it is money thrown away. Also, a belt dressing must be applied properly and not too thick. On new belts no trouble is experienced, but on old belts full of grease and other foreign matter, a good dressing will if used with care, finally force all impurities and dirt through the grain and to the outside of the belt where they can be removed easily. This is an important factor and should never be ignored. A great mistake, made by many when using a liquid belt dressing, is that after a few applications, they give up in despair. It often takes weeks of treatment with constant supervision to get a belt in proper shape.

The belt that runs with the slack side the wrong way must be taken into consideration also. If the load is constant the belt can be treated the same as other belts. If it is necessary to take up such a belt, it should never be drawn too tightly. The larger the belt, the better the chance to eliminate power losses by maintaining it at the proper operating tension.

Slipping belts often cause trouble by generating static electricity and have been the cause of a number of fires, by discharging a static spark into combustible gases, dusts, and so on. In several cases, oilers and operators have met with injury as a result of receiving a static discharge which caused them to fall or suddenly jump into danger. All of this could have been eliminated by applying the proper methods of using and treating belts.

Good results may be obtained with canvas and rubber belts by giving them the same treatment with belt dressings, as in the case of leather belts, although the existing conditions must be studied to acertain the extent of treatment needed, and sometimes exceptions have to be made.

Persistent effort and careful analysis of individual belt problems will more than repay those concerned for the time thus spent. Give your belts a chance, and they will do all that is expected of them.

Auburn, N. Y. W. L. JOHNSON.

Keeping Pulleys True Improves Operating Conditions

IN SOME cases it is found that a wood pulley gets out of round after long and faithful service. Frequently this is due to a shock or intermittent load. This out-of-round-ness of the pulley imparts a jump to the belt it drives which is objectionable and accentuates the intermittent or shock load. The belt is under a stress due to the intermittent pull and also because it may have been installed with the short side or radius of the pulley up. In this way the countershaft is kept in constant vibration, and a stress is put on the lineshaft.

Lineshafts which run out of true, as is often the case on lines of shafting with many pulleys on them, are frequently the result of the pull of belts springing the shafts to one side. This is made more pronounced by those out-of-round pulleys which exert a jerk upon the shaft with each revolution. Sometimes this out-of-round condition is due to the wrong use of interchangeable bushings. It is seldom advisable to use bushings of one make with pulleys of other makes, to mix old and new bushings, or to use mixed bushings of different makes. Also homemade bushings seldom run true. In addition there is the natural warping of the wood when exposed for long periods alternately to dampness and heat. Any one or several of these conditions may be the cause of wood pulleys getting out of shape.

Our factory has made a practice of going over wood pulleys and correcting those which are in really bad condition. Any pulley more than ¼ in. out of round is corrected, and on some machines this tolerance is usually cut in half.

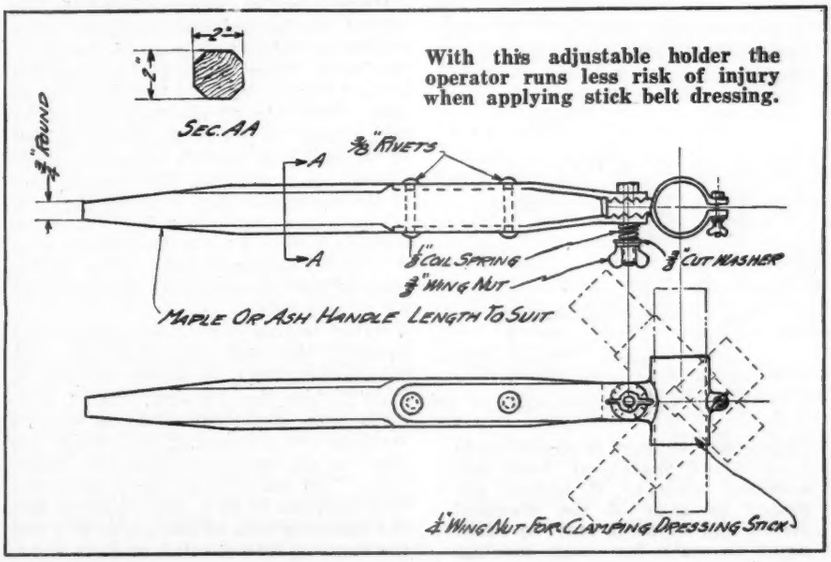
The pulleys are taken down and their periphery turned in the lathe. We have three arbors which correspond to the three sizes of lineshafting in the plant. The pulleys are mounted upon these arbors, using the identical bushings and bolts in the pulley. After being turned, the pulleys are given one coat of orange shellac, which is allowed to dry, and is then sandpapered and another coat applied before they are returned to service. This work is done when the particular machine driven is not in use. The work is ordered on a form which is made out after inspection and notifies the *Maintenance Department* that a certain pulley is to come down when the machine driven by it is taken out of service for sufficient length of time.

Adjustable Holder for Applying Stick Belt Dressing

BELT dressing ordinarily comes in the form of a thick semi-liquid or in sticks. The semi-liquid dressing is usually heated and applied with a brush to the belt when in motion. Stick dressing is held against and moved across the surface of the moving belt and the friction wears or melts off some of the dressing.

Although the stick type of dressing is commonly held in the hand when applied it is a somewhat hazardous process, particularly on high-speed belts, where metal or other fasteners are used, or when the stick is worn short. A safer method, as recommended by the National Safety Council, Chicago, Ill., is to use the adjustable holder, shown in the accompanying illustration, when applying stick dressing. This holder was made by D. S. McEachern, fire and safety engineer, Semet-Solvay Co., for such use.

When applying the dressing, the holder should be held at right angles to the belt. The head of the holder may be adjusted to the proper angle by loosening the ⅜-in. wing nut, adjusting the holder to the position desired, and then tightening the nut. The dressing should be applied to the outgoing side of the belt so that in case the stick dressing should catch on a belt fastener, the holder would be thrown out of the operator's hands and away from the pulley. Also, when applying semi-liquid dressing with a brush it is safest to hold the brush to the outgoing side of the belt at the pulley so that the hand or brush are not pulled into the pulley as would otherwise be the case.



With this adjustable holder the operator runs less risk of injury when applying stick belt dressing.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contribution are always welcome.

Wire Used as Gage When Boring Babbitt Bearings

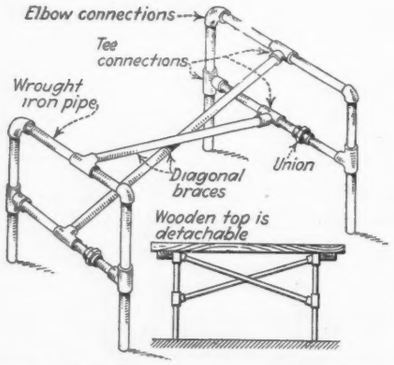
A SPECIALTY factory with no metalworking department has an all-around repairman who does the work of electrician, mechanic, carpenter, and anything else there is to do. Among his activities is the care of a number of motors, even to their rebabbitting. However, he has no lathe and so sends his babbitted bearings to a near-by machine shop for finishing.

The method of obtaining the correct bore is unique. He owns micrometers and measures his shafts accurately. He then takes a piece of wire, points it at both ends, smooths the ends off, and sends it to the machine shop with instructions to bore the hole so that when the piece of wire is held upright in it there will be a swing of $\frac{1}{16}$ in. at the top while the bottom is held stationary. This is a simple and easily-made gage, which so far has given satisfactory results. DONALD A. HAMPSON.

Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Easily-Made Pipe Supports for Workbench

WHERE a small workbench is desired, for either temporary or permanent use, the pipe frame construction, shown in the accompanying sketch, is very satisfactory. This can be easily made up in any convenient width or length, as practically every shop has the necessary tools for doing the work. It is not necessary to use new pipe, as such a bench can be made up of discarded pieces.



This bench support is easily made from short pieces of pipe and standard fittings. If unions are placed in each of the diagonal struts, the supports may be taken apart to make for easier moving.

The method of assembling the legs and the diagonal struts gives a rigid construction. If it is desired to make such a bench portable, unions may be added to the diagonal struts so that they may be easily taken apart. The wooden bench top may be secured to the supports with hook bolts or straps, whichever is the more desirable, especially if the bench is to be taken apart to be moved.

Washington, D. C. G. A. LUERS.

Comment on "Laying in a Chorded Split-Loop Winding"

IN THE September issue of INDUSTRIAL ENGINEER, A. C. Roe shows a diagram of a split-loop winding. I do not understand how the leads are connected to the commutator bars nor what connections are made with leads *1* and *12*, for example. I would like to see a diagram of the winding connected to a 12-bar commutator.

Los Angeles, Calif. JOHN BANTOU.

* * * *

This type of winding can be used for armatures having as many bars as slots when using two wires in hand, or for three times as many bars as slots when using three wires in hand. However, this winding is generally used only with armatures having two or more times as many bars as slots. In the chorded split-loop winding the wire is not cut after winding each coil except to put on sleevings.

One sleeve for each coil is all that is needed for low-voltage machines. The sleeves should be put on all of the starting leads. Then instead of cutting the wire, a loop is made at the end of each coil. One side of the loop should be long enough to use as the finishing lead of the coil just wound, while the other side of the loop forms the starting lead of the next coil. Fig. 1 shows the coils all in place without being cut from start to finish. This is the same as Fig. 2 in the September issue. The beginning of the winding is at the free lead F^{12} in slot *7*.

After testing for opens, shorts and grounds, the next step is to cut open each closed loop, as shown in Fig. 2. This divides the winding into 12 complete coils and each slot contains a starting and a finishing lead, which applies to all two-layer armature windings. The table with Fig. 2 gives the lead numbers in each slot; thus we find the finishing lead of coil *11*, or F^{11}, and the starting lead of coil *1*, or S^1, in slot *1*. These numbers are also used to designate the coils and the sequence in which they are put on the armature.

We now have the windings separated into 12 coils, as in any two-layer winding, except that the formed coils are placed in adjacent slots in consecutive order. The bottom or starting leads and top or finishing leads are brought out in regular order, which makes it an easy matter to lay down the bottom leads. In any hand-wound armature, that is, an armature on which the coils are wound directly into the slots from the reel of wire, the starting leads S^1, S^2, and so on, are considered the bottom leads and the finishing leads, F^1, F^2, and so on, are considered as the top leads.

The next step is to find the bottom leads of consecutive coils in adjacent slots. In hand windings the best coil to start with is the last coil put on which is always visible, such as coil *12* in Fig. 2. The starting or bottom lead S^{12} is in slot *2*. Now assume that in this armature the leads are brought over to the commutator bars on the center line of the coil with lead S^{12} bent in towards the bars between slots *4* and *5*. Using the last coil prevents the chance of making the costly mistake of bending the lead of S^{12} around the opposite side of the armature to bars between slots *10* and *11*.

After sorting out the start or bottom leads from the finish or top leads in each slot, as has been done in Fig. 2, and putting down the bottom leads of the last coil, we next take the bottom

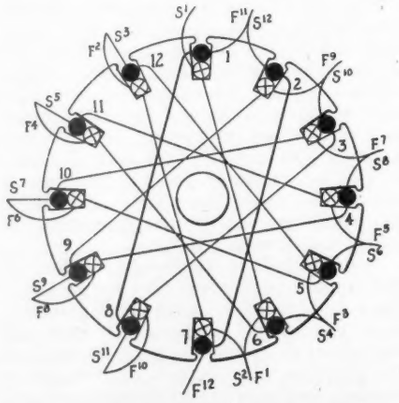
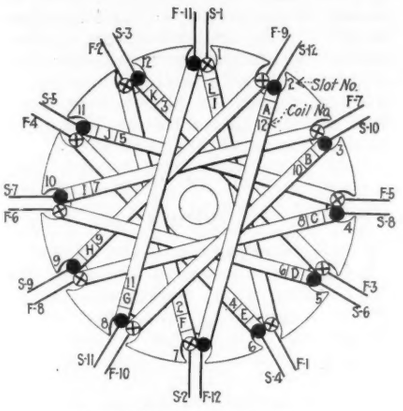


Fig. 1—Complete winding diagram for a chorded split-loop winding. In this diagram the top half-coils are represented by black dots, while the circles with crosses in them indicate the location of the bottom half-coils. S^1 is the start of the first coil, F^1 is the finish of the first coil, S^2 is the start of the second coil and so on through the winding.

lead in the adjacent slot in a clockwise or counter-clockwise direction. The direction of pick-up does not matter providing we choose a bottom or starting lead each time from an adjacent slot, and that the leads are put in commutator bars on the proper side of the last coil leads. This means that no leads



Slot No.	Lead No. Start	Lead No. Finish	Slot No.	Lead No. Start	Lead No. Finish
1	1	11	7	2	12
2	12	9	8	11	10
3	10	7	9	9	8
4	8	5	10	7	6
5	6	3	11	5	4
6	4	1	12	3	2

Fig. 2—Procedure in connecting a chorded split-loop winding to the commutator.

Letters *A*, *B*, *C*, and so on indicate the coil sequence and direction of pick-up. Starting leads (S^1, S^2, etc.), and finishing leads (F^1, F^2, etc.), indicate the order of winding. The table shows the leads that are placed in each slot.

should be crossed over the first leads put down, but should be placed in back of or ahead of the first leads, according to the direction of pick-up.

In Fig. 2 the letters *A*, *B*, *C*, and so on marked on each coil indicate the direction of pick-up and the coil sequence. Let us first select the bottom lead S^{12} of coil *A* in slot *2* and put it down as explained above. Then S^{10} of coil *B* is placed in slot *3;* lead S^8, coil *C*, in slot *4;* and so on until all the bottom leads have been laid. If the starting and finishing leads have been properly marked while winding and the coils wound in the correct order, there will not be any chance of mistakes in following the above procedure. Suppose a mistake were made in marking leads F^{11} and S^{10}, for example, and the finishing lead F^{11} of coil *7* or *I* were marked S^{10} while connecting. Then we put down lead F^{11} after lead S^{12} and coil *I* would be in a strong magnetic field when under commutation. This would cause sparking, heating of the winding and jerky operation of the armature.

In Fig. 2 the coil numbers which show the order of winding each coil onto the core are given under the letters, which indicate the sequence of connecting the coils in the proper order to the commutator. Thus, coil *A* is coil *12* or the last one wound and the first one connected to the commutator. Coil *B* is the tenth coil wound on and the second connected; coil *C* is the eighth coil wound on and third coil connected, and so on.

Comparing the winding order, as coils *1, 2, 3,* with the order of connecting, the bottom lead of coil *1* is the last bottom lead put down; coil *2* is the sixth coil connected and coil *3* the eleventh to be connected. It is obvious what would happen if the leads were put down in the same order as the coils are wound, or if they were placed without cutting open the loops.

Wilkinsburg, Pa. A. C. ROE.

Simple Device for Removing Pinions or Pulleys from a Shaft

A SIMPLE device which I have found to be very handy for removing pinions or pulley from a shaft is shown in the accompanying illustration. To make this puller, bore a hole lengthwise of the center through a piece of 3-in. shafting, 8 in. long, and tap it for a standard 1½-in. bolt. Make the 1½-inch bolt 22 in. long pointed on one end and square on the other. Thread this bolt for practically its entire length and screw it into the piece of shafting. The pointed end of the bolt should be just sharp enough not to slip out of the shaft center when the puller is in use.

Three pieces of flat iron, ⅝ in. by 2 in. by 10 in., should be welded at right angles to the shafting, as shown, spacing them 120 deg. apart. These pieces should be welded very securely to the shaft as the usefulness of the puller depends on the strength of the welded joints.

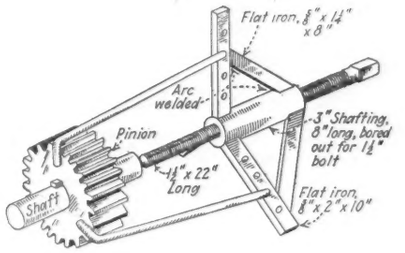
Three pieces of flat iron, ⅝ in. by 1¼ in. by 8 in., should be used as braces, with one end welded to the shafting and the other end to the horizontal 10-in. pieces. These braces must have their ends cut at an angle so that they will make a good fit and can be neatly welded.

Four holes 1 in. in diameter, for the puller hooks, should be drilled approximately 2 in. apart in the 10-in. arms.

The puller hooks consist of three pieces of ⅞-in. round iron, 22 in. long. Bend these at right angles, 2 in. from each end, so that one end can be hooked into the puller arm and the other end back of the pulley or gear to be removed from the shaft. Three sets of hooks should be made, so that on small gears or pulleys the set will be easier to handle. We use three sets of hooks of the following lengths: 8 in., 14 in., and 20 in. All of these are made of ⅞-in. round stock.

In operation the puller is placed against the gear or pulley to be removed, with the hooks inserted in the holes in the puller arms which will bring them as close as possible to the face of the pulley. The other ends of the hooks should be placed behind the gear or pulley. The 1½-in. bolt may then be screwed against the shaft with a wrench, thus forcing the gear or pulley off the shaft.

The puller described above was made for heavy service and weighs about 35 lb. Lighter material could be used, but the above specifications are recommended. As an example of what this puller can do fan spiders have been removed from a 2 1/16-in. shaft when they fitted so tightly that we had to use a 36-in. wrench on the bolt, with a piece of 2-in. pipe slipped over the handle for extra leverage.



A gear or pulley is removed from its shaft by screwing in the threaded bolt.

If the bolt should become jammed and hard to move, run it through a threading machine. Also tap out the threads in the shafting, so as to keep the puller working freely at all times. Different hooks may readily be made to fit special gears or pulleys and can always be reused.

Chief Electrician, Shevlin Hixon Co., Bend, Ore. WM. B. CONE.

Simple Method of Removing Fan Stators From Frames

QUITE often in removing stators from the drawn steel frames of 8-in. to 16-in. Westinghouse fans, considerable damage is done to the windings. The following simple procedure has been used with success in some shops, for the purpose of preventing such injury.

A 16-in. fan frame is 4 29/32 in. outside diameter. The core is 4¾ in. outside diameter which makes the thickness of the frame or shell approximately 5/32 in. When the end frame is removed from this size fan the core or laminations protrude approximately ¼ in. beyond the frame. Take a piece of 4½-in. iron pipe about 4 in. in length and bore it out to 4 1/16 in. for a distance of 2¼ in. from the end. Face the end off straight while the pipe is in the lathe, using a tool that will leave a square shoulder at one end of the bore to prevent the core from jamming in the pipe.

Place the part of the core protruding from the frame into the pipe with the 5/64-in. shoulder resting on the end of the pipe that was faced off and while holding it in this position and keeping the fingers clear of the joint thus formed, strike the other end of the pipe on a block or solid bench with enough force to drive the core out of the motor frame or shell.

This same method can be applied to fans of other sizes, by using the proper size of pipe, and it will be found that the time and labor saved on the first few jobs will more than justify the expense of making these tools for the various sizes of fans.

Denver, Colo. JOHN E. HOLTMAN.

New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Flux to Use in Gas Welding

A FLUX for oxyacetylene welding has been placed on the market by the Hoxite Co., Stamford, Conn. Tests, which have been conducted with the flux, are said to show good results on cast iron, malleable iron, aluminum, government bronze, Monel metal, brass, semi-steel and other metals.

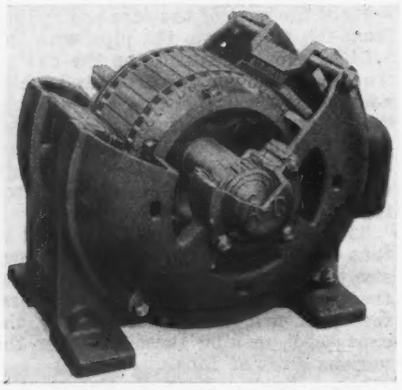
Some of the characteristics claimed for the flux are that it will not blow off the welding rod, that there is no frothing, and that it gives off no disagreeable fumes.

New Roller-Bearing Motor

AFTER two years of experimental and development work, the Allis-Chalmers Mfg. Co., Milwaukee, Wis., has placed on the market a complete line of 25- and 60-cycle squirrel-cage and slip-ring, induction motors in ratings up to 200 hp., equipped with Timken tapered roller bearings. These motors are being produced in addition to this company's well-known line of sleeve bearing motors. After designs of bearings and mountings had been made, a number of motors of various sizes were built and tested under actual operating conditions of belt, gear, chain and coupled drives, for a sufficient length of time to insure satisfactory service before the line of motors was put on the market.

The bearings are mounted in dust-proof, grease-tight enclosures and packed in grease so that further lubrication is required only at infrequent intervals. The bearings are mounted with a light press fit for both the cone and cup and do not require the use of a lock nut or other means of holding the races in place. This also facilitates the removal of the bearings.

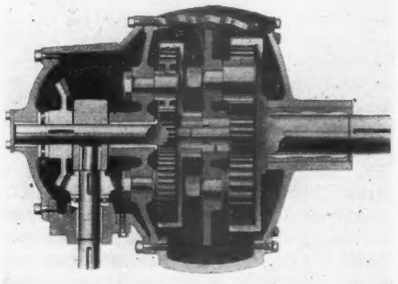
In addition to the bearings, special attention has been given to many other features of design in this line of motors.



The frame is made of steel with feet cast integral, so as to withstand shocks when used with crushers, grinders and other machinery. In applying the motors to Allis-Chalmers centrifugal pumps, severe conditions of moisture are often met; hence the coils are thoroughly insulated with waterproof varnish and baked. In saw mills, flour mills and cement mills, motors must operate in very dusty and dirty places. The openings in the housings and frames for ventilation are so placed in vertical planes, that falling objects cannot enter the motor.

Right-Angle Spur Reducers

THE new line of IXL right-angle drive spur reducers recently developed by Foote Bros. Gear & Machine Co., 215 N. Curtis St., Chicago, Ill., is designed to meet the requirements for



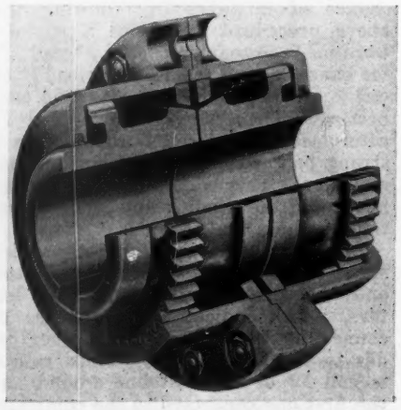
reduction gears that must operate in confined spaces where sufficient room is not available for the mounting of standard straight-line drive units and where it is necessary to change the direction of the power drive. This reducer is very similar in appearance to the standard, straight-line drive speed reducers except that the high-speed shaft projects at right-angles to the axis of the slow-speed shaft. The change in direction of the power drive is accomplished by means of bevel or miter gears mounted in the high-speed end. The secondary bevel or miter gears are mounted on the high-speed driving shaft which is concentric with the slow-speed shaft.

Except for the addition of the bevel gears in the high-speed end, the design of the machine is identical with the standard IXL non-planetary spur gear speed reducer. The high-speed pinion is integral with the high-speed shaft and delivers the power through three idler gears set at 120-deg. angles to a large rotating integral gear, which is securely fastened to the slow-speed shaft. The high-speed pinion, together with the idlers, internal gear and slow speed shaft, comprise the entire mechanism for a single reduction train which can be repeated to secure greater reduction ratios.

By changing the size of the pinion and internal gear and the relative size of the bevel gears in the high-speed end, it is said that almost any desired relation may be obtained between the speeds of the high-speed and low-speed shafts. The manufacturer produces these right-angle spur reducers in a large variety of standard sizes and reduction ratios, in horsepower capacities ranging up to 150 hp. and reduction ratios as high as 350 to 1.

Flexible Couplings for Shafts

THE accompanying illustration shows the construction of the Pool flexible coupling which is announced by The Poole Engineering and Machine Co., Baltimore, Md. This coupling consists of six parts: two hubs having an external gear on each meshing with internal gears in two sleeves which are bolted together and two aligning rings which are fitted in the two sleeves. The outer faces of the teeth on the hub are formed spherically, which, it is stated, provides a self-aligning bearing for the connecting sleeve, so that if the two shafts are out of alignment the sleeve assumes a neutral position with a lubricated bearing on the spherical surface of each shaft hub. This coupling is enclosed and so is protected from dust and dirt and is said to operate equally well in either direction on continuous or reversing service, and at high or low speed. All parts are made of high-carbon, forged steel and are interchangeable. Oil holes are provided in one side of the coupling flanges, into which oil should be poured until it runs around the shaft hub. When the coupling is running, the oil spreads out under the pressure so that the sleeve bearings and gear teeth operate in a bath of oil. Any good grade of lubricating oil can be used. These couplings have been designed, it is claimed, so that they are stronger than the connecting shaft and can be used on any shaft without consideration of a utility factor. Coupling ratings are given, however, which indicate the maximum horsepower the coupling will transmit under good service conditions, at 100 r.p.m. Factors are used for severe conditions.



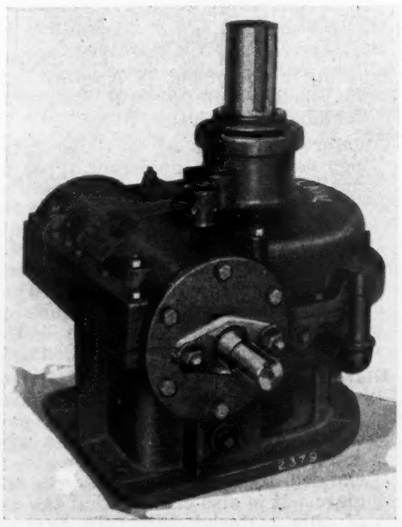
Machine Limit Switch

A MACHINE limit switch of compact design has been developed by the Monitor Controller Co., Baltimore, Md., with over-all maximum dimensions of 4 in. by 2⅛ in. by 2¼ in. This switch is designed to handle pilot circuits of d.c. or a.c. starters and controllers and, it is said, can be used as a limit switch to provide overtravel provision, as an interlock switch on machines, or for other similar purposes. It is constructed to be dust-tight. This switch is made in two types; one type has normally open contacts and the other has normally closed contacts. The standard type of construction has copper-to-copper contacts of large size which, it is stated, operate under heavy contact pressure. For special applications, these switches can be provided with silver contacts.

Worm Reduction Gear for Vertical Shaft Drives

THE accompanying illustration shows a worm reduction gear for vertical shaft drives recently developed by the DeLaval Steam Turbine Co., Trenton, N. J. The gear casing supports the worm bearings and also the lower bearing of the driven shaft. while the upper shaft bearing is held by the casing cover. The oil is carried at such a level that the worm and gear wheel dip into it, thus insuring ample lubrication. The lower wheel shaft bearing is always immersed in oil and has spiral oil grooves.

A small reciprocating oil pump is incorporated in the casing cover to provide oil for the upper wheel bearing and thrust plate. The plunger of the pump projects downward against a

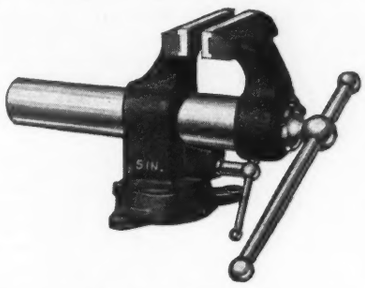


cam, which is located just outside of the thrust plate of the bearing. The rotation of the cam actuates the plunger which, by means of ball check valves, draws in oil through the suction pipe projecting from the under surface of the cover down into the oil in the casing. Suitable filling and drainage openings, together with a try-cock, provide for control of the oil level.

For larger, high-speed reductions, where it is not desirable to immerse the worm and wheel on account of fluid friction, a positive pressure oiling system is used to feed oil to all the bearings and to the worm threads and gear teeth at the contact points. A full line of these drives is made and drives can be furnished with the shaft extending either upward or downward.

Drop-Forged Bench Vise

A NEW line of drop-forged bench vises, one of which is shown in the accompanying illustration, has been brought out by The Fulton Drop Forging Company, 112 So. Main St., Canal Fulton, Ohio. These are sold under the

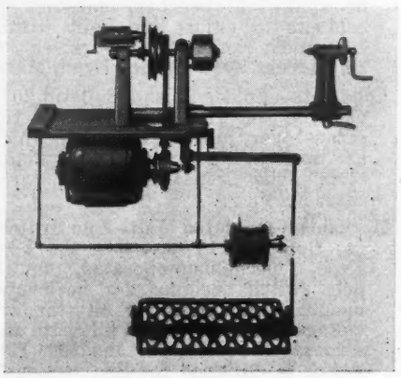


trade name of the Dropfo vise and are made with either a solid stationary base or with the Wedgelok swivel base. These vises are made entirely of interchangeable drop-forgings in four sizes: 3 in., 4 in., 5 in. regular and 5 in. heavy duty, and it is stated that the various sizes of these vises weigh less than the corresponding sizes of ordinary vises. The jaw plates are knurled as they are forged and are doweled on.

The swivel type is so constructed that tightening the jaws automatically tightens the base, or it may be tightened independently where it is desired to use it as a stationary vise.

Small-Coil Winding Machines

ANNOUNCEMENT is made of the production of a small bench type coil winding machine for winding small solenoids, by the Armature Coil Equipment Co., 2415 Forestdale, Ave., Cleveland, Ohio. The machine, which is shown in the accompanying illustration, is operated by a ¼-hp., 1,800- or 1,200-r.p.m., ball-bearing motor. The winding spindle in the headstock is also provided with ball bearings. Control



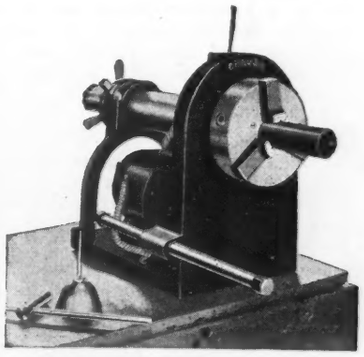
over starting and stopping is through the foot treadle and clutch in connection with a brake. A three-jaw, 3-in. universal chuck is provided for holding any job or fixture. A four-wheel Veeder counter of 10,000 turn capacity which resets to zero with one turn of the crank, is attached. The bracket for receiving supply spools has a tension device working against the side of the spool through a spring tension which can be adjusted quickly to suit the needs of any particular job.

Magnetic Switch for High Frequencies

A NEW enclosed switch, bearing the designation CR-7006-S-3, has been placed on the market by the General Electric Co., Schenectady, N. Y. This switch was designed for wood-working applications where frequencies higher than 100 cycles are necessary. A special coil and magnet frame construction is used, without increasing the over-all dimensions of the switch. The rating of the switch varies according to the frequency of the circuit on which it is used; at 120 cycles, it will be operated on 220 volts; at 150 cycles, on 275 volts; at 180 cycles, 330 volts, and so on for any other corresponding intermediate voltage and frequency. The switch is built in two-pole form to conserve space and provide one disconnecting switch for all motors.

Power-Driven Pipe Tool

ANNOUNCEMENT is made of a new power-driven pipe threading and cutting tool by The Borden Co., Warren, Ohio. This is known as the No. 44 Beaver power drive, in which the pipe revolves while the tools are stationary. The unit weighs 230 lb., is portable, and is operated by a ½-hp., heavy-duty motor. It is stated that any



type of pipe threading tool may be used in connection with this outfit, to handle pipe ranging from ¼ in. to 2 in. diameter, inclusive. By means of a universal shaft this unit may be used to drive a No. 41 Beaver die stock for cutting threads on 2½-in. to 4-in. pipe, or with a No. 61 Beaver die stock to cut threads on 2½-in. to 6-in. pipe. The socket end of the shaft has a standard opening so that it will fit into the square of the pinion on any make of geared die stock.

Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Stationary Tachometer—Bulletin 1080 describes a new Jagabi Type B stationary tachometer which operates on a centrifugal principle, runs in either direction, and may be used for the continuous indication of speed.—James G. Biddle, 1211-13 Arch St., Philadelphia, Pa.

Small Motors—A circular, Form 308, illustrates and describes the principal features of this company's single-phase, ⅛- to 5-hp., repulsion-induction motors, direct-current motors of ⅛ to 1½ hp., and polyphase (two- or three-phase) motors of ⅛ to 7½ hp. —Master Electric Co., Linden and Master Aves., Dayton, Ohio.

Automatic Switching Equipment—Circular 67716-A, Class 17, describes automatic switching equipment for indoor a.c., reclosing feeder service from 440 to 7,500 volts, lists its advantages, describes the mechanism and principle of operation.—General Electric Co., Schenectady, N. Y.

Cable Splicer—A circular describes a method of splicing cable conductors by the use of the Canton, a special cable splicing clamp around the overlapped ends. With this clamp, it is claimed that a 300,000 circ. mil cable can be spliced in 10 min. with 4 in. of overlapped ends.—The American Mine Door Co., Canton, Ohio.

Ball-Bearing Motors—A circular describes the Marble-Card ball-bearing d.c. motors and generators in sizes from ½ to 75 hp.—Marble-Card Electric Co., Gladstone, Mich.

Window Cleaning Solution—A circular describes Sunburst, which is claimed to be a harmless liquid which will quickly remove deposits of carbon, grime or rust from factory windows and skylights without injuring the paint, putty or frames. — The Guerson-Stewart Corp., E. 76th and W. & L. E. R. R., Cleveland, Ohio.

Graphic Pressure Recorders—Bulletin 625 describes the use of graphic pressure recorders, their construction and use.—The Esterline-Angus Co., Indianapolis, Ind.

Grease—A circular describes Kent grease which is recommended for use on gears and bearings in connection with a grease gun system of pressure lubrication.—Kent Lubricating Co., Colby-Abbott Bldg., Milwaukee, Wis.

Fusible Primary Cutout—Circular GEA-99 describes and illustrates the expulsion Type E, Form A, fusible primary cutout rated at 30 amp., which is porcelain housed and suitable for use on circuits carrying up to 7,500 volts.—General Electric Co., Schenectady, N. Y.

Water Softener—Bulletin 509 describes the Zeolite water softener which provides water without hardness by the pressure filter method. — Graver Corp., East Chicago, Ind.

Belt Cutter—Circulars describe the K-D belt cutter which may be adjusted to cut or trim down belts to any width desired.—The Klinger-Dills Co., 129 N. Jefferson St., Dayton, Ohio.

Automatic Motor Starters—Bulletin 1016-B describes the E. C. & M. automatic motor starters for non-reversing, direct-current motors. These are made in two general designs according to the manner of mounting the apparatus, and the rating.—The Electric Controller & Mfg. Co., Cleveland, Ohio.

Hand-Operated Air Hammer — Circulars describe the Maxson air hammer which is operated by a hand crank, and is claimed to be able to deliver from 750 to 1,500 effective blows per minute. This hammer does not require any electric or air connection and, it is said, will bite ¼-in. to 1½-in. holes through concrete at the rate of 1 in. per min. It may also be used for rivet driving and with chipping tools.—Maxson Sales Co., Monadnock Bldg., Chicago, Ill.

Squirrel-Cage Motors—Circular GEA-6 describes the 500 Series of general-purpose, continuous-duty, constant-speed, squirrel-cage motors of 15 to 150 hp. at 220, 440, 550 and 2,200 volts, and the types of control equipment used.—General Electric Company, Schenectady, N. Y.

Insulation Resistance Testing—Bulletin 130 describes the Model D Megohmer, Bulletin 125 the Junior Megohmer, and Bulletin 135 the 2-in-1 Megohmer. Each bulletin shows the application of these in making insulation resistance tests.—Herman H. Sticht & Co., 21 Park Row, New York City.

Ventilation Equipment—Circulars describe and show applications of the Norblo exhaust fans which are designed to meet varying conditions and hard service.—The Northam Blower Co., W. 65th St. and Wheeling & Lake Erie R. R., Cleveland, Ohio.

Adjustable Lighting Fixtures—Catalog 3 describes the Axcess system of adjustable lighting fixtures which may be applied to benches, machines or cabinets to adjust the light within convenient range of the work.—Samson Axcess System, Inc., Lynn, Mass.

Condulets—Folder 27 and Bulletin 2076 describe and give dimensions of the screw-cover, junction condulets which are made in 2½-in. and 3½-in. diameters.—The Crouse-Hinds Co., Syracuse, N. Y.

Mechanism-Operated Multi-Pole Switches—Bulletin 116 describes the 8800 Type, mechanism-operated, multipole switch designed for horizontal mounting and built for all standard voltages from 15 to 132 kilovolts and amperages of 300, 600 and 800. This switch is designed for line sectionalizing, substation switching, or for any condition where a ruggedly-built, easy-operating switch is required for horizontal mounting.—Electrical Engineers Equipment Co., 710 W. Madison St., Chicago, Ill.

Ball Bearings—Price lists and descriptive matter cover the Gurney deep-groove, radial and double-row ball bearings. — Marlin-Rockwell Corp., 402 Chandler St., Jamestown, N. Y.

Valves—A circular describes Valve No. 7, a many-purpose valve with a quickly renewable disk.—Crane Co., 836 S. Michigan Ave., Chicago.

Small Motors—Folders describe the Janette special motors rated from 1/20 to 1/3 hp. for a.c. and d.c. current. Special attention is given to the bearings and the method of lubrication.—Janette Manufacturing Co., 556-558 W. Monroe St., Chicago, Ill.

Transformer Data—No. 5 of a series of monthly bulletins contains four interesting data sheets on the connection of transformers.—Moloney Electric Co., St. Louis, Mo.

Switchboard Instruments—Circular GEA-25 describes round-pattern, switchboard instruments, 7½ in. in diameter, for alternating or direct-current service. Circular 66016-A describes horizontal, edgewise alternating or direct-current switchboard service instruments.—General Electric Co., Schenectady, N. Y.

Socket Wrenches—Catalog B describes the Snap-on interchangeable socket wrenches and attachments with square or hexagonal sockets for use on automobiles or industrial work. Giant socket sets are provided for the larger sizes of nuts.—Motor Tool Specialty Co., 14 E. Jackson Blvd., Chicago, Ill.

Expansion Shells—A circular describes the Phillips self-drilling, expansion shells for attaching pipe hangers and other similar purposes. One end of the shell is arranged as a drill, expands while drilling, and the shell remains in the ceiling. The hanger or other equipment is screwed into the shell.—Phillips Drill Co., 1537 Cortland St., Chicago, Ill.

Counters—A series of sectional catalogs describe the numerous types of small counters for counting revolutions or strokes, elevator mileage recorders, special counters for textile machinery which record operation in yards or other units, and magnetic counters which may be placed at some distance from the machine on which the record is taken. — The Veeder Mfg. Co., Hartford, Conn.

Glare Prevention—A circular describes "Blu-EE" which is a special preparation to place on window glass, particularly on skylights and west windows, to prevent eyestrain it is claimed, by eliminating shadows and glare. It is also claimed that the use of this material will help to keep the plant cooler in summer.—Park Chemical Co., 3818 Edwards Road, Cincinnati, Ohio.

Carbon Brushes—A catalog describes and lists Carenco carbon brushes for motors and generators, gives instructions for ordering and descriptions of the various grades, with illustrations of the different types and their applications.—Carbon Engineering Co., 1700 8th Ave., Milwaukee, Wis.